PRODUCT ENGINEERING

AUGUST, 1943

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PRODUCT ENGINEERING

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Subscribers may encounter delay in receiving their copies of Product Engineering. Such delay is caused by wartime strain on transportation and postal systems, a situation beyond the Publisher's control.

IN THIS ISSUE

Cover Picture

Army 16-in. coastal defense gun hurling a one-ton shell towards an invisible target 15 to 25 miles away.

Detroit Delivers the Guns

Before the war, automotive engineers spent considerable time redesigning pleasure cars and trucks for greater efficiency and lower production costs. No design was ever static; research was always continuing. When ordnance production replaced automotive production, these same engineers went to work on gun designs. Stampings, weldments, powder pressings and castings replaced difficult-to-machine parts and hard-to-get forgings. Result: the United States is producing better guns and more of them, many more than the Axis will ever hope to have. Highlights of the engineering behind the guns will be found on page 467, illustrated with before-and-after engineering drawings and photographs.

Powdered Metal Parts

From its first applications to pressed and sintered porous bearings, powder metallurgy was developed for the manufacture of small intricate metal parts. Saving in machining expense was the main feature. Under the impetus of war demands, new

powders, new techniques in the making and treatment of the pressings, and the development of more effective manufacturing equipment have created technical and economical reasons for the use of powdered metal pressings. On page 472, a staff article based on data collected in the field, clearly points the way to "tested applications" wherein powdered metal pressings will make possible design features not otherwise economically obtainable.

Tapered and Stepped Columns

Long before it was necessary to conserve every pound of material possible in the design of machines and structures, engineers were interested in the problem of determining the lightest weight column to support a given end load. Such problems are always complicated by the confusion which exists in the application of the various standard column formulas. Professor Church in an analytical discussion, see page 499, based on the formulas of Euler and J. B. Johnson, outlines a practical solution.

Ethyl Cellulose

Of the various cellulose plastic materials developed, the most recent and unusual is ethyl cellulose, characterized by toughness, flexibility, solubility in a wide variety of cheap solvents and resistance to alkalis. William Koch, of the Experiment Station of the Hercules Powder Company, a pioneer in the development of ethyl cellulose, discusses the characteristics and properties of this material beginning on page 506. Charts and tables present important data. Typical applications point to many possible uses of ethyl cellulose when it becomes generally available after the war.

Valves Used in Hydraulic Transmission

Along with the application of hydraulic circuits to the many fields where this fluid transmission was used, it was necessary to develop means for controlling the power flow. Valves were designed which serve as the control center, and make possible sequence of operations. The common control valves used in the machine tool field are illustrated on pages 510 and 511.

Unground Bearings

Unground bearings have been the means for expediting production in an aviation plant. Article on page 488 shows how alteration of designs to use this type bearing effected appreciable monetary savings without reducing the quality of the product.

Roller Bearing Retainers

A unique method for solving a problem that involves production, choice of materials, standardization and design flexibility, that can be used by engineers as an approach to many design problems, is illustrated in the article "Stampings Eliminate Machining in Roller Bearing Retainers," page 504, by R. R. Kilian, development engineer of the Rollway Bearing Company.

Curbs for Magnesium Corrosion

Corrosion properties have been largely accountable in the past for rejection of magnesium in favor of other metals. Magnesium's tendency toward corrosion has been overcome to a large degree through alloying, chemical surface treatments, paint, and insulation against galvanic action. The fourth of a series on designing with magnesium on page 493 gives detailed information on methods employed to combat corrosion.

Flight Test Signals Converted to Instrument Readings

A flight recorder developed by the Consolidated-Vultee Aircraft Corporation for transmitting as many as 100 different instrument readings while the plane is in flight, was described in the July issue. The sequel on page 512 relates how it is possible for the ground recording instruments to convert the signals, as sent out by the plane, into values associated with accepted engineering standards.

Drawn Aluminum Box Shapes

Supplementing data presented in his article "Drawn Cylindrical Shapes of Various Aluminum Alloys," which appeared in the July issue of PRODUCT ENGINEERING, T. H. Hazlett, research engineer at Lockheed Aircraft Corporation, rounds out the discussion with more observations and design rules on the kindred subject "Drawn Box Shapes of Various Aluminum Alloys," page 517.

Die-Forged Parts

Use of die-forgings, their advantages and various applications are discussed by Charles L. Tutt, Jr., in an article starting on page 521. Design and specification of die-forgings and the limitations of available equipment are pointed out. Since demand for die-forging is greater than can be supplied because of wartime conditions, PRODUCT ENGINEERING has been presenting substitute methods of fabrication. These methods have often proved more satisfactory than forgings, but there remain countless other applications where high strength and other factors give die-forgings undisputed superiority.

Wiring Diagram Symbols

Symbols adopted by the Machine Tool Builders Association for representing switches, relays, resistances and other electrical units. See page 537.

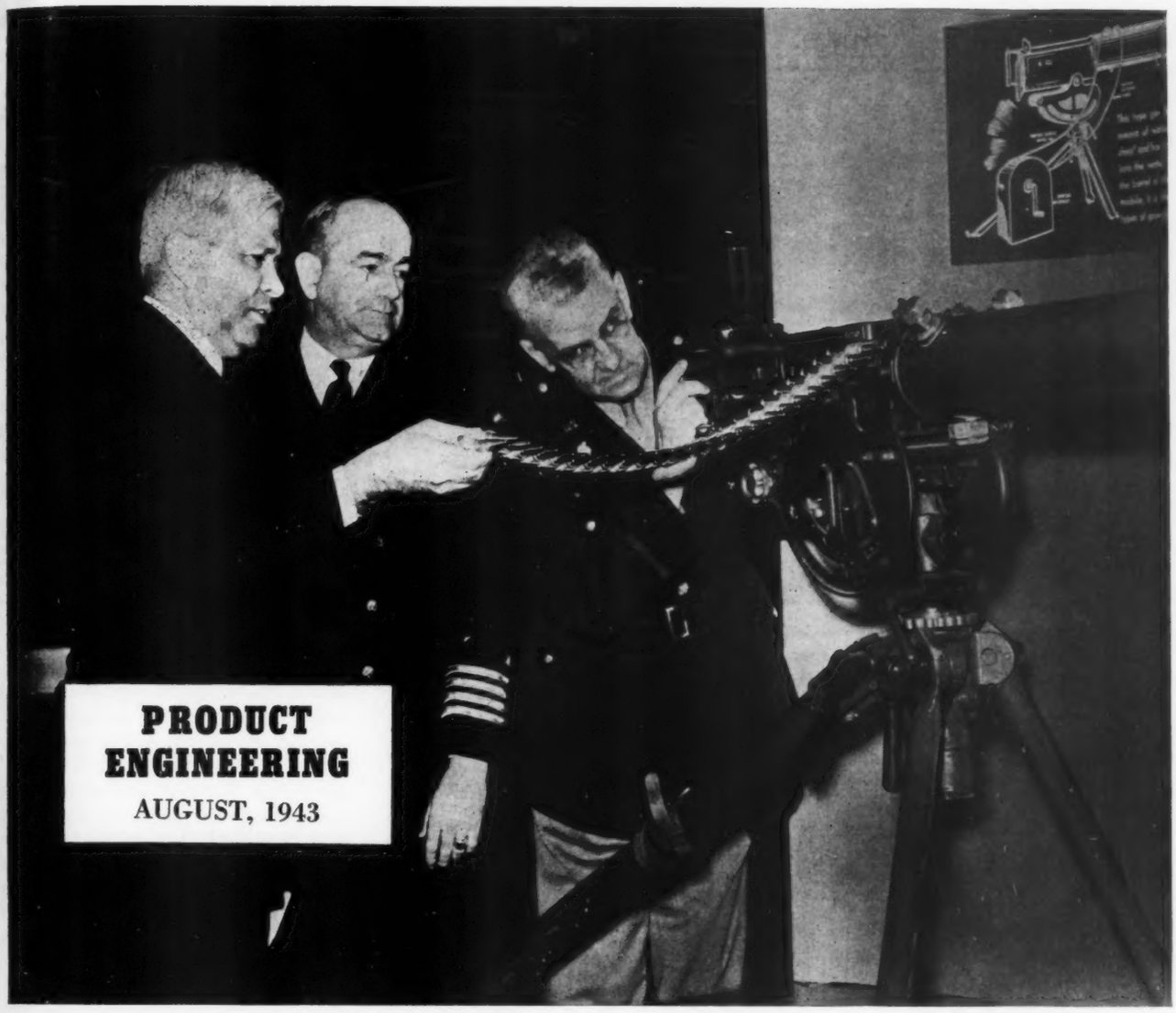
WHAT'S COMING

Plastics Symposium

All designers are looking ahead thoughtfully to the post-war period. Many are now thinking about the materials, types of construction and devices that are relatively new and that they might incorporate in their future designs. Quick comprehensive surveys of the things available are of immeasureable help in pointing the way. In the September issue, Product Engineering begins a series of inserts—the first one on plastics, giving basic data and information on materials, manufacturing techniques, constructions and devices. Others to follow will include electronics, electric motors, controls, finishes, metals and other materials.

How Designers Can Benefit Through C.E.D.

The future of every design engineer in the country will be affected by the success or failure of the Committee for Economic Development because success will mean practically unlimited design activity and failure might lead to everything we are fighting against—totalitarianism. C.E.D. is a voluntary cooperative organization of business men. Already it has stimulated much activity in postwar design. What its plans are and how it works will be described completely in September P.E. so that design engineers can make the best possible use of what C.E.D. has to offer, participate in its activities or contribute to its efforts.



PRODUCT ENGINEERING
AUGUST, 1943

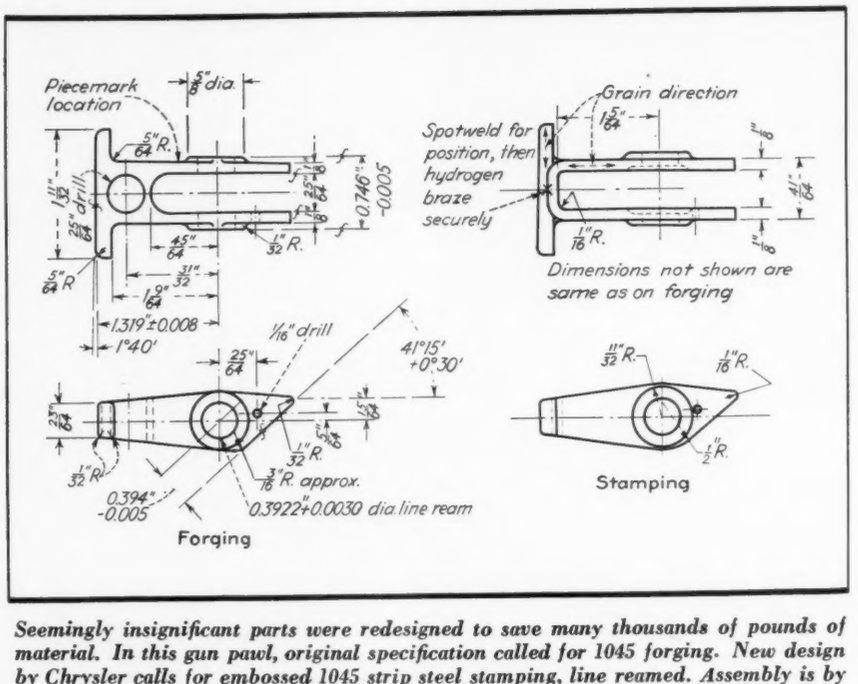
Cooperation of automotive engineers and Army and Navy Ordnance officers made possible the water-cooled machine gun under examination. Inspecting the gun at the Detroit plant of General Motors are (left to right): C. E. Wilson, president of General Motors Corp.; Captain A. W. Wotherspoon, inspector of Naval Ordnance, and Colonel E. H. Besse, commanding officer of Fort Wayne, Mich.

Automotive Design Techniques In Mass Production Of Ordnance

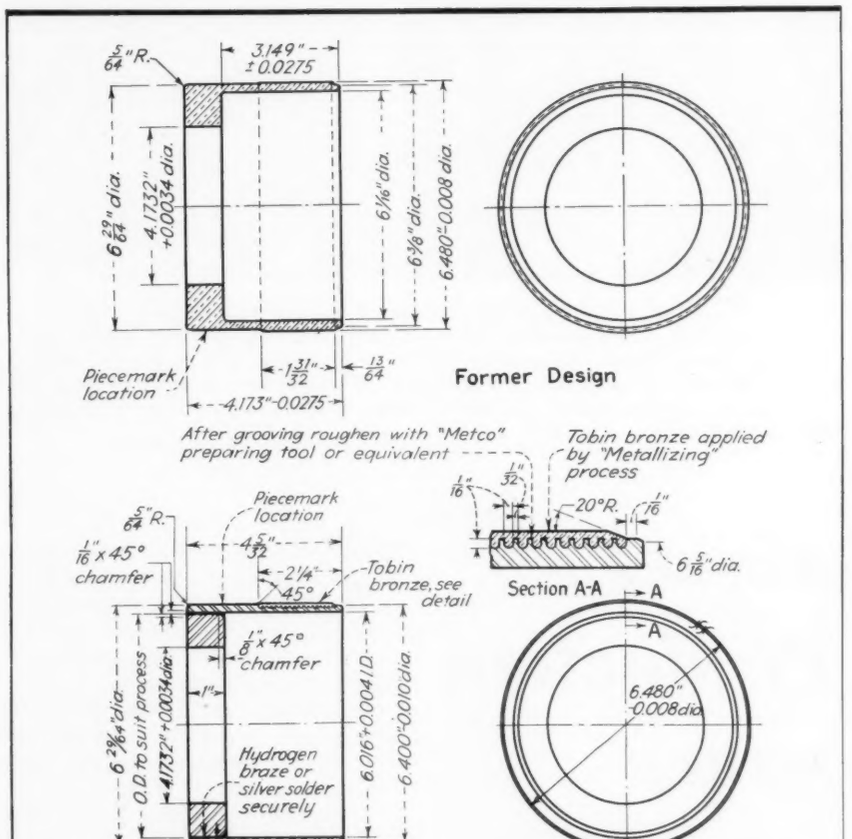
Conversion of existing automotive equipment and redesign of component parts of lethal weapons are described as important instruments for placing ordnance on a swift-moving production basis. Redesign of component parts for mass manufacturing techniques include stamping, welding, powder pressing, metallizing and high-strength casting. Savings in critical materials, manpower and machinery were made without sacrificing efficiency.

THE automotive industry is constantly engaged in research and experimentation, whether working on peacetime cars and trucks or wartime weapons. This ceaseless activity in peacetime seeks to reduce costs, improve product efficiency and boost sales. In wartime, this endeavor is motivated by a single purpose: more weapons of greater efficiency.

Adapting ordnance to high production meant considerable redesign to take advantage of new techniques. Although all present-day war weapons are high-precision, complicated mechanisms, Detroit engineers pitched in and immediately began to study component parts for possible changes. In this redesign work they had one hundred percent cooperation from Army



Seemingly insignificant parts were redesigned to save many thousands of pounds of material. In this gun pawl, original specification called for 1045 forging. New design by Chrysler calls for embossed 1045 strip steel stamping, line reamed. Assembly is by hydrogen brazing. Over 120,000 lb. of steel are saved per year by this change alone



Bronze sprayed on steel. Metallizing a spring recoil sleeve by spraying low-grade bronze on seamless tubing eliminated a critical bronze casting on the Bofors gun. Top drawing shows the original casting. Lower drawing shows the Chrysler redesign. Note the detail showing surface preparation before metallizing is done

and Navy Ordnance engineers, for Ordnance too was anxious to get high production of these weapons, and to save manpower, materials and machinery.

Importance of design engineering in war is aptly expressed in the General Motors report for the year 1942, which states:

"The technical requirements of military products must always remain the responsibility of the armed forces. They alone are cognizant of the tactical purposes for which the equipment is to be used, and how those purposes can best be accomplished. However, it is the responsibility of industry to contribute its manufacturing and engineering experience, in cooperation with the armed forces, to the end of attaining an ever-advancing technology in the weapons of war. In competition with the enemy it is essential to achieve and to maintain technological superiority. . . .

"Know-how is an all-inclusive term. It reflects all phases of the task of getting the job done. It includes the coordinated efforts of the entire personnel. The engineering phase of know-how involves two approaches, quite separate but at the same time closely related. One is the technique of design which has a direct bearing on what might be called the 'efficiency in combat' of any particular type of war product. The second approach concerns the technique of production. This involves in war production the maximum effectiveness of manufacturing equipment and facilities and the minimum consumption of man hours and material to effect a given result. The techniques both of design and production importantly influence costs.

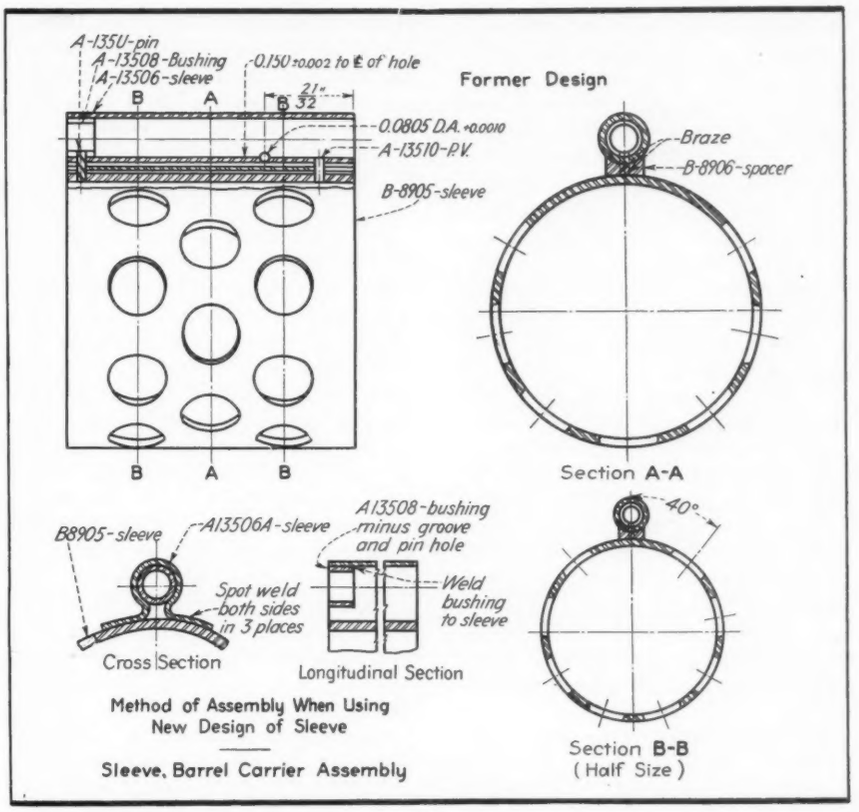
"Perhaps the clearest appreciation of what has been accomplished in advancing production techniques may be gained from the fact that these improvements have made possible voluntary reductions in selling prices amounting to $361,288,825. Of this amount, $177,980,415 applied to deliveries made up to the end of 1942. The balance of $183,308,410 will apply to deliveries made subsequent to 1942 under existing contracts."

Stampings Replace Machined Parts

Many of the last automobiles built utilized stamped and welded construction for high-strength sub-assemblies. The Chrysler front spring suspension was an outstanding example. Two stampings were welded together to form a complicated box section that

proved stronger than the forged subassembly it replaced. This same thinking carried over into gun manufacture has released considerable machine and foundry capacity. In such a small item as a gun pawl, formerly a forging, now a strip steel stamping embossed and line reamed, 91,200 man hours and 120,000 lb. of steel were saved on a year's production. By re-engineering this 2 in. part, Chrysler engineers saved material equivalent to 2½ General Sherman tanks. On the .50 caliber machine gun produced by the A. C. Division of General Motors, the use of two stamped rolled-up sections replaced two pieces of seamless tubing and two special form-milled parts. On the Chrysler-built Bofors gun, the water jacket support spacer was formerly an 8 lb. forging costing about 19 cents a lb. About 4 lb. of material was machined off. The Chrysler redesign, worked out with the cooperation of Ordnance engineers, is rolled-up sheet steel butt welded. It weighs only 4½ lb., requires no machining, and is stiffer. Cost is about one-eighth of the former design.

These represent only three isolated examples of the use of stampings. Hundreds of others could be cited. Many have already been described in Product Engineering to show how built-up formed metal components reduce product cost, often increase operating efficiency and save production time.



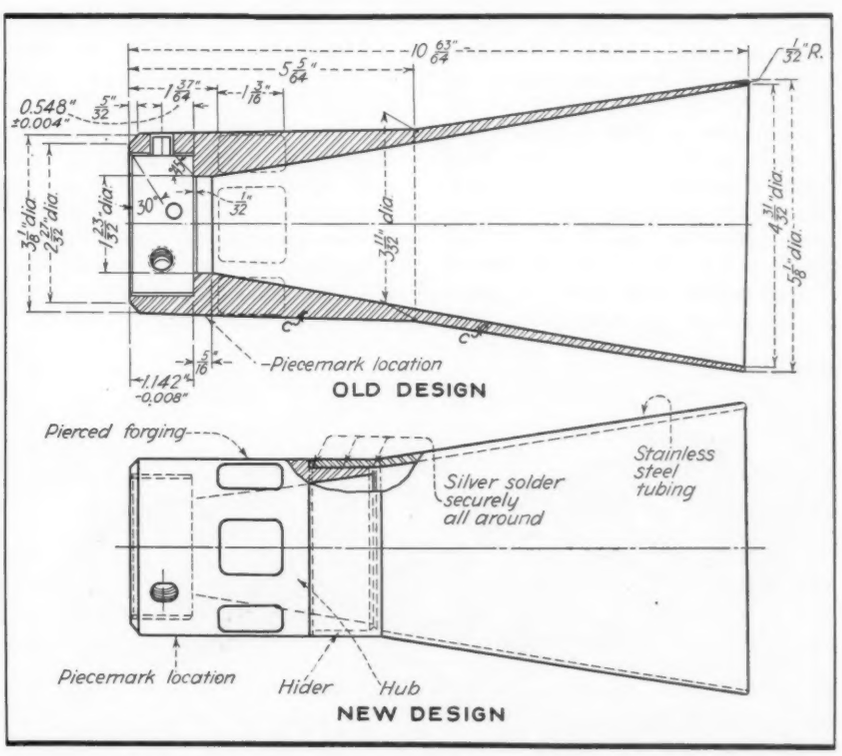
Simplification of assembly and material savings were made in this machine gun barrel carrier originally assembled from six parts which included two pieces of seamless steel tubing. Special form milling was required on supporting pin, and the assembly was joined by brazing. In the redesign, formed sections are spot welded together

Built-Up Components

Built-up sections often combine forgings and tubing. On the Oerlikon gun, the barrel spring casing was originally specified as a solid nickel-moly steel forging weighing 56 lb., which had to be machined down to 6 lb. Pontiac engineers figured out a method of using steel tubing welded to a forged base. This assembly weighed 14 lb., and was then machined to 6 lb. The redesign resulted in saving 42 lb. of critical nickel-moly steel. Six machining operations were eliminated and $18 to $20 savings per piece realized.

Chrysler's forepart of the Bofors gun body is currently a fabricated assembly, consisting of a steel tube to which the buffer bracket, sight pad and flange are arc-welded. Formerly a steel casting was used, but much extra metal was required in the part to avoid trouble with porosity, shrinks and other defects. To avoid scrap losses and burdensome machining, the design was changed to welded construction.

In Chrysler's flash hider on the



New assembly technique saves time, reduces cost. Silver soldering by induction heating joins the die formed seamless tubing to a pierced forging, replacing a solid steel forging machined down from 40 to 10 lb. The silver soldered joint is moisture proof. The new construction saves almost 5,000 man hours per month

Bofors gun a bell-mouthed assembly is screwed onto the muzzle end of the gun to conceal the powder flash. Originally this flash hider was machined from a solid steel forging weighing 40 lb., the finished weight being 10 lb. Before tooling, Chrysler engineers changed the design to a pierced forging, to remove some of the excess stock. The pierced forging still presented difficult machining. Complicated fixtures and critical machine tools were required to produce this small forged part.

It was reasoned that the bell-mouthed portion of the flash hider could be produced in simple press tools in one operation, in which one end of the tube would be swaged down by the die ring and the other end flared by the punch. The first try, using 4 in. tube, was successful, one end being swaged down to 2⅞ in. and the other end flared to 5⅛ in. Moreover, the proper tapering thickness was obtained throughout the bell mouth.

The nut portion of the flash hider is now a pierced forging, removing only 1½ lb. of metal. The tapered end of the bell-shaped piece is cleaned up for a silver-solder joint. The two parts are assembled, then placed in an induction coil to raise the joint to 1,175 deg. F. for silver soldering. This process does not scale or distort the work. Besides possessing adequate strength, the silver-soldered joint is moisture proof, because the solder completely fills the space between the two parts.

Many tons of steel are saved per month, and six machines of a critical nature were re-assigned to other work. Some 4,893 man-hours, or an equivalent number of machine-hours, are saved each month by this application of automotive "know-how" to manufacture of a single Bofors part. Thus the ability of automotive designers to analyze and redesign small components is an important factor in saving man-hours and reducing costs.

Silver Soldering

Silver soldering has been found to be advantageous in the redesign of Chrysler ordnance. For example, the waterjacket on the Bofors gun was originally a welded structure. Design of the gun is such that this jacket must be absolutely true as it guides the gun barrel. Welding of the joints often caused warpage and scaling. Also the weld metal could not penetrate the entire joint. Thus rust was a problem. When silver solder is used, joint clearance is held to 0.0015 to 0.002 in. and the part is induction heated to 1,275 deg. F. The solder flows uniformly throughout the joint making a watertight seal. No warpage problem is encountered. Further improvement in the design was accomplished by substituting a rolled-up sheet for the original seamless steel tube, without sacrifice of strength.

General Motors engineers have made extensive use of ArmaSteel in their redesign activity. ArmaSteel, a pearlitic malleable iron, has a strong uniform structure and can be cast to close limits. Its yield strength is comparable to steel forgings in the 1035-1050 range. Because the material has resistance to shock and fatigue it has been used to replace many critical forgings. On machine guns, the trunnion adapter, support barrels, flash hider cones, breech lock cams and mount adapters are now cast ArmaSteel. On the 20 mm. aircraft cannon manufactured by Oldsmobile, ArmaSteel castings replace the forgings used for buffer housing, magazine slide and sear cover plate. On these three parts alone savings per gun are estimated to be $8.69. On this same cannon, ArmaSteel is used for the muzzle brake ferrule and dashpot piston, replacing machined bar stock and saving $3.55 per gun.

ArmaSteel first came into prominence when it was used for automotive pistons at the time aluminum was no longer available. The increase in weight was not great because the heavy wall thicknesses were not required. Such applications naturally led automotive designers to consider it as a replacement possibility for forged and machined ordnance parts. AC Spark Plug engineers found out, for instance, that use of ArmaSteel saved 63 lb. on the light machine gun and 80 lb. on the heavy gun. Also, the ease of machining made possible a production rate increase of 25 percent. With the extensive knowledge gained from the use of this material in ordnance designs, it is probable that in the future cast steel, forgings, and tubing will be replaced with it.

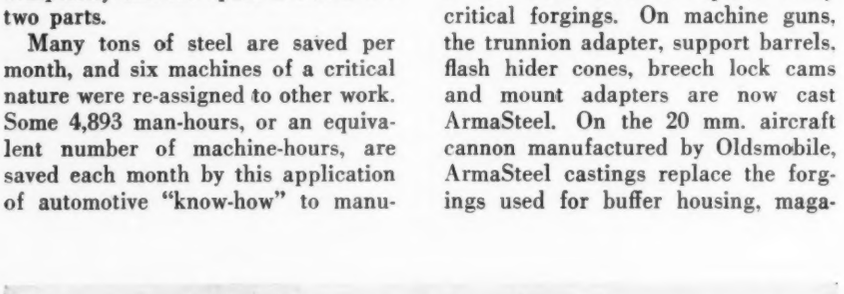
Powdered Metal Parts

War necessity had led to the wider and wider use of powdered metal parts, not only because of savings in machining time but because of the need to save copper. In many cases, iron-coppers and pure-iron lubricating bearings replace bronze bearings. One large thrust bearing, which Amplex makes, is 18 in. in diameter, an indication that powdered metal designs may be successful for large components. Before the war, powdered metal parts seldom exceeded 3 lb. in weight. To date, items weighing up to 60 lb. have been made of powdered metals.

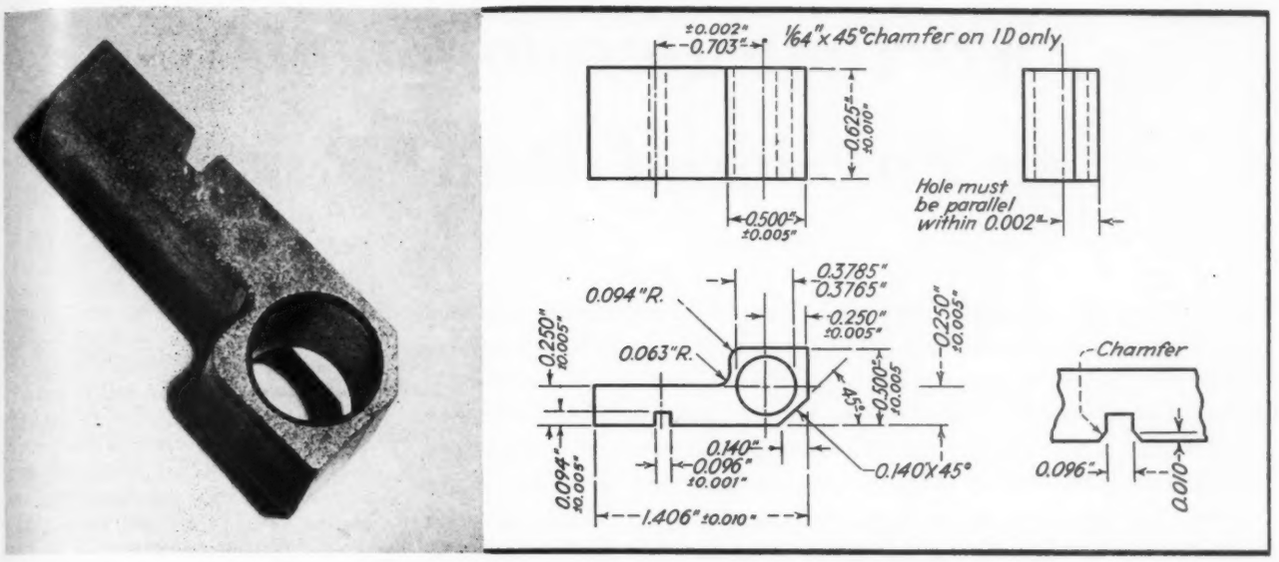
War experience has brought out two facts about powder-metal parts: they can be processed to possess physical properties comparing favorably with cast or wrought products, and that physical and electrical properties can be "tailored" to the requirements of the application.

Metal Spraying Saves Bronze

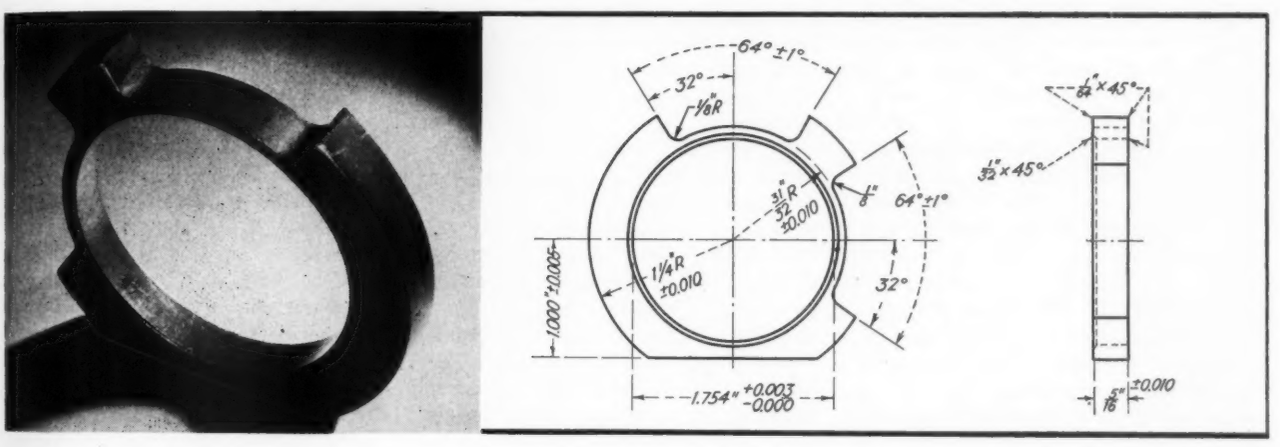
One of the most interesting of recent developments in the redesign of ordnance involved the spraying of low-grade bronze or steel to produce a bearing surface equivalent to that of manganese bronze. This development was pioneered by Chrysler engineers for the Bofors barrel spring recoil sleeve. Original specifications called for a 16 lb. manganese bronze casting. Seeking a means of conserving this



ArmaSteel casting reduces machining time 50 percent. In this example, cored holes are provided in casting which is produced at very near finished dimensions. Former design required removal of 15 lb. of material from 4 in. O.D. steel tubing



Typical powdered metal pressings as used in ordnance. Such parts, requiring little or no machining, can have "tailor-made" physical properties to meet specific application requirements



critical material the engineers substituted a steel sleeve on which they sprayed 2 lb. of Tobin bronze. Tests showed that this design was equal to the original in frictional qualities, had equivalent resistance to seizure, and that shear strength was good, although tensile was low.

For the success of such an application, surface preparation is important. The bond between the sprayed metal and steel surface is entirely mechanical. Final method used to insure adequate bond was to groove the steel tube in a lathe, to approximately 0.025 in. in depth. The second step was to use a special tool with a toothed wheel applied normal to the tops of the ridges. This roughens the surface and tends to spread the ridges to form dovetail grooves that mechanically hold the sprayed metal.

So successful has this application of spraying been, that it will probably be adapted to other ordnance parts where, in order to secure certain bearing surfaces, special bronze castings have been specified. Savings on the Bofors amount to 14 lb. of bronze per gun. Savings in cost have not yet been estimated.

The redesign cases that might be cited are numerous, for there is hardly a component part of ordnance that has not been studied over and redesigned by automotive engineers. Every effort has been made to adapt parts for the most efficient use of materials, machinery and manpower. Overcoming almost insurmountable odds in tackling the job of making precision armament on a mass production basis, these engineers have not only produced the goods, but have actually improved the efficiency of our armament. The secret lies in the amazing amount of production "know-how" in Detroit, the research manpower available. Above all, it lies in the teamwork evidenced when Army-Navy and automotive engineers combined talents to put ordnance on an assembly line basis. Hitler's head start of ten years has been overcome in less than three years. On many ordnance items, America is not only outstripping the Axis in production, but most important, in the efficiency of the weapons. Worth noting is the statement on the future based on this performance as mentioned in General Motors' annual report for 1942:

"Under the national war program established at the beginning of 1942, an amazing amount of war material was produced. In particular, the speed and efficiency with which the automobile industry and some other large industries adapted themselves to the production of war material have astounded skeptics. The performance is a dramatic demonstration of the ability of American industrial management and the soundness of the principles of free enterprise. If reconversion to civilian products can be accomplished with equal speed at the end of the war, the danger of a postwar depression will be greatly reduced. There is no fundamental reason why this should not be possible."

Wartime Developments In Powdered Metal Parts

In addition to economies resulting from reduced machining and elimination of scrap, advantages of powdered metal pressings include the use of more readily available materials. Through the mixing of different metal powders and compositions thereof, controlled and unusual physical and other properties can be achieved. Design shapes and contours not economically obtainable by machining can now be formed. An accompanying table lists the properties of pressed metal powders produced by five companies.

AMERICAN engineers are finding that adoption of "performance tested" powdered metal parts for armament components not only speeds war production, saves labor and materials, but often results in an item with superior physical and other properties for the specific application. For in addition to the well known "oil-less" bearing, the powdered metal parts industry is currently supplying structural components for aircraft, ordnance, and military vehicles in bronze, iron-copper, pure iron and even tool-steel analyses. These structural parts, made by briquetting and sintering processes, have the advantage that they can be assembled with little or no machining.

To those who think of powdered metal parts as oil-less bearings weighing a few ounces, it is news that bronze bearings 18 in. or more in diameter and weighing upwards of 60 lb. are in production. Most of the ferrous parts are smaller, rather intricate bearings and structural pieces, but here too some heavy sleeve bearings are being made. Three facts stand out from a survey of the powdered metal parts now commercially supplied: 1. The physical properties attainable are much higher than one might expect from a product that originates as a mass of powders; 2. tailor-made properties have been realized in a number of instances; 3. tolerances on dimensions have been held to a few thousands and even tenths of thousands.

These achievements rest upon a solid foundation of research and commercial development by powdered metal parts producers in peacetime, and intense cooperation by customers during the war. Engineers and designers working upon armament problems have recognized the field for powdered metal parts in five particulars:

1. As a means of saving copper. Oil-less bearings were used by the millions in peacetime. Armament applications are staggering—a four-engine bomber alone uses 4,000 oil-less bearings. To save copper consumed in bronze bearings, iron-copper and later pure iron, self-lubricating bearings were developed to serve as alternates for bronze bearings. For many applications, all three types are now used interchangeably at speeds up to 4,000 r.p.m. Special products are available also when service conditions are severe, for example, in valve seat grinders where speeds of 30,000 r.p.m. are encountered. In one application bearing loads at zero velocity range up to 60,000 lb. per sq.in. These latter products can be highly corrosion resistant.

2. Material losses in the form of machining scrap are avoided. Scrap produced in machining many armament parts from bar stock and forgings runs between 30 and 70 percent, is sometimes higher. In contrast, a powdered metal part weighing 10 lb. is produced from exactly that weight of powders. The tie-up of more than 5,000,000 lb. of strategic material in the form of scrap will be avoided during the current year by one large manufacturer who uses powdered metal parts for a large number of bearings and structural components.

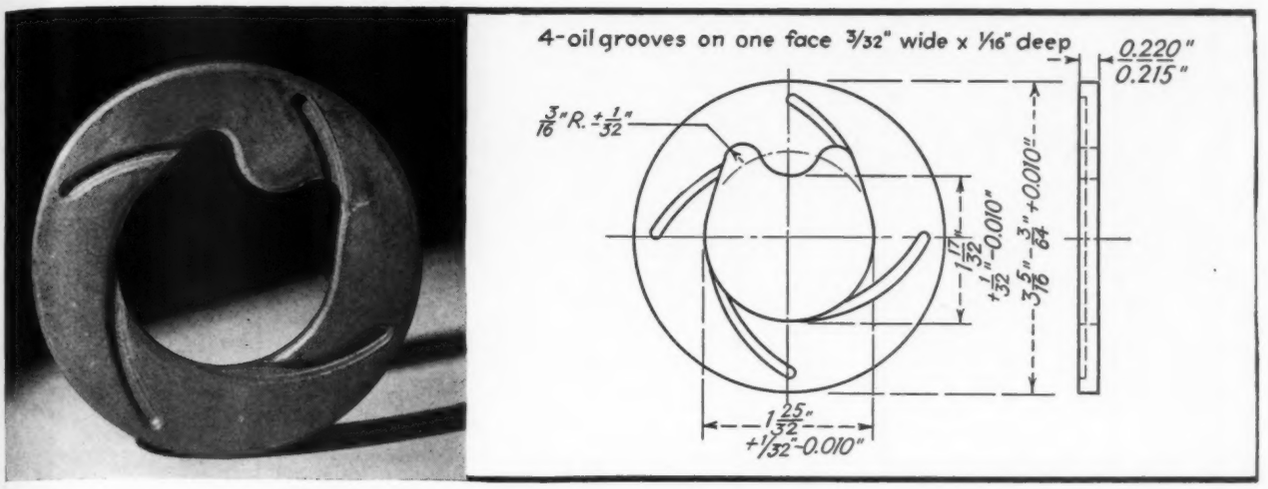
3. Considerable manpower can be saved in the production of intricate parts. Time cycles for producing powdered metal parts are comparatively short. The forming, or briquetting process, ordinarily requires from 1 to 15 sec. per piece. For example, a bronze gun-sight bracket is briquetted in 12 sec., whereas to contour machine this piece would take 2 hr. These differences in processing time for intricate parts constitute the reason why the Chrysler Corporation saved 5,000,000 man hours in 1942 upon the production of 20,000 sets of parts (90 parts to a set) for a gun mount. Producing these parts required but a fraction of their facilities.

4. A war plant often is able to secure shipment of powdered metal parts in less time than is required to design the tooling for a conventional machining layout, aside from building fixtures and tools and installing machines. Briquetting dies for powdered metal parts can be made in a matter of days or a few weeks and all processes employed are of the mass-production variety.

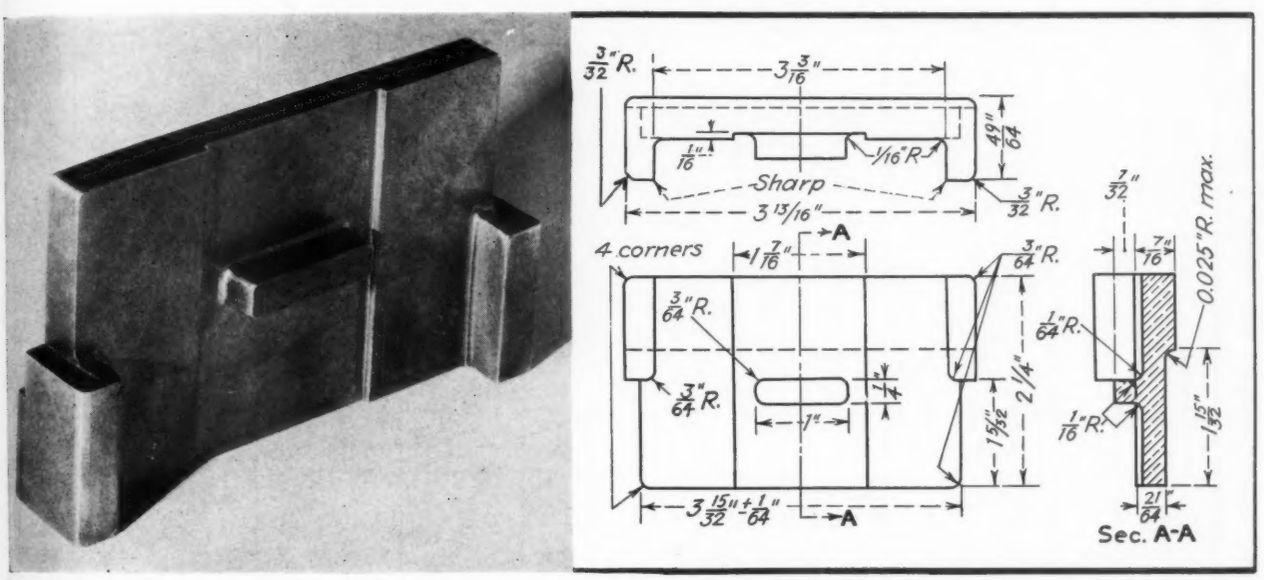
5. Cost of powdered metal parts is usually less than for items made by better known methods.

Physical specifications established for other materials are not ordinarily met in powdered metals, because their processing is so special that variations from customary standards are almost certain to be the rule. Some remarkable properties have been realized, more or less experimentally, such as steels with a hardness of Rockwell 65 C. and a tensile strength of 140,000 lb. per sq. in. The safest procedure is to establish satisfactory performance by tests and use the specifications as a check for uniform quality. Thus on armament work, a powdered metal part is customarily listed as an alternate material with its own specifications.

An accompanying table lists specifications that five producers have made available for publication. These relate to what might be termed standard materials. It is possible for the manufacturers to give much better service to the user if complete data concerning the loading, service conditions and other factors are supplied. Rather complete freedom in compounding the powders for a part is enjoyed by



Made of self-lubricating bronze, this flat bearing has four integral oil grooves to meet a certain military application. The two faces of the bearing are held flat and parallel within 0.001 in., otherwise commercial tolerances apply



High-density bronze is briquetted in 12 sec. to produce this gun-sight bracket, as compared to 2 hr. for contour machining. All dimensions are held to a tolerance of ± 0.008 in. After drilling a couple of holes, this piece is ready for assembly to a cannon

the powdered metals industry, and tailor-made characteristics can often be supplied. Thus compromises frequently exacted by forging or casting processes are overcome.

For example, consider the pole piece and rotor for a small electric motor for aircraft controls. The motor manufacturer requested that these parts be made from the original steel specification, which had been selected for ease in machining but at some sacrifice in electrical characteristics. After studying product application, the powdered metal company furnished parts produced from an alloyed material that give more efficient service and improved electrical properties, and cost less.

Despite the tremendous wartime achievements in application of powdered metals to structural parts of intricate shape and close tolerances, a word of caution is introduced. The hardness of powdered metals cannot be indicated, for example, by any tests because of porosity, which is present in some degree except in those parts finished by a heavy rolling or pressing process. The mass hardness of a powdered metal part may often be much less than for a wrought article. On the other hand, the crystal hardness of a powdered metal part will be identical with that of a steel of the same analysis given the same heat-treatment. It is true that powdered metal parts of much lower physical properties will often perform better than a cast or wrought alternate, even though the explanation may be difficult to evaluate.

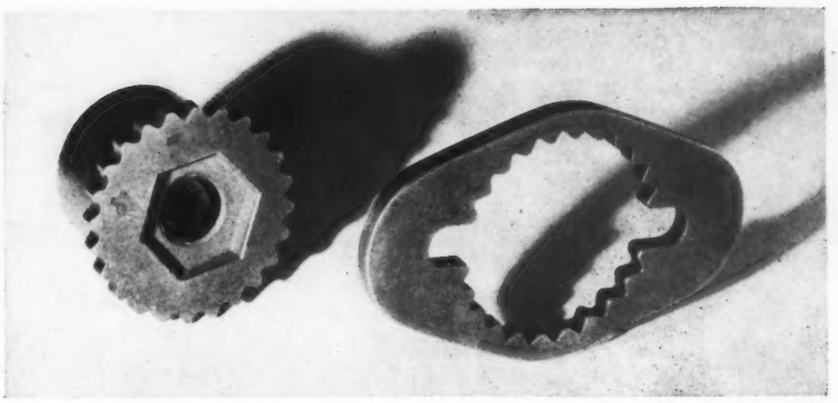
Six Steps in Process

Innate differences may be realized better from a brief description of the manufacturing process, which may involve six principal steps: 1. Mixing, or compounding, of powders on the basis of composition, purity, particle size, flow, density, voids, and intrinsic hardness or softness; 2. powders are rescreened to make sure that particles of uniform range in size are made available for compacting; 3. powders are fed automatically into the briquet-

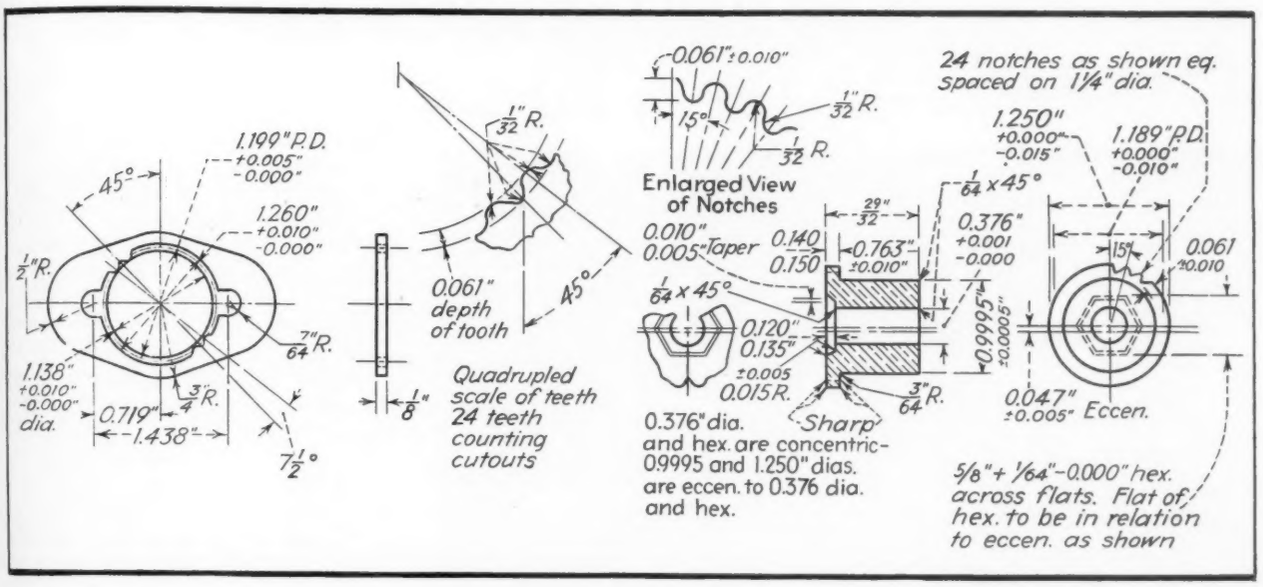
Physical Properties of Bronze, Iron-Copper and Iron Powdered Metals in Sintered Condition

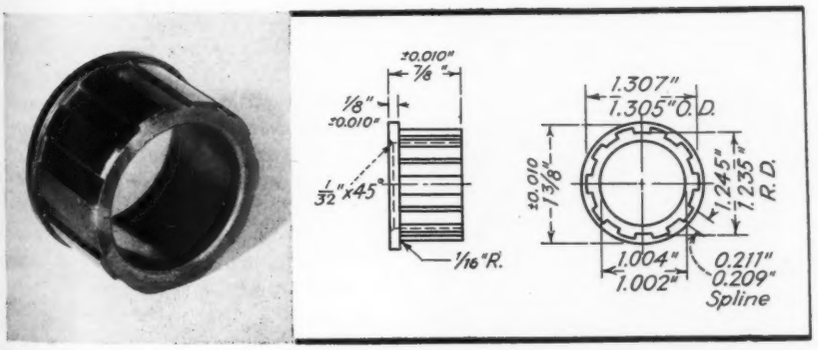
Material	Ultimate Strength Tensile	Ultimate Strength Compressive	Loading Static	Loading PV Factor	Load for Permanent Set of 0.001 in.	Load for Permanent Set of 0.005 in.	Elongation percent	Hardness Brinell	Porosity Oil by Vol. percent	Weight per cu. in.	Coeff. Thermal Exp. per deg. F.
BOUND BROOK—OIL LESS BEARINGS:*											
Compo Bronze (88.5 Cu, 10 Sn)..... Bearings and parts	12,000	69,000	7,500	50,000	10,500			25–35	27	0.228	9.8×10^{-6}
Powdiron 55–P (95 Fe, 5 Cu)..... Bearings and parts	12,000	140,000	15,000	50,000	16,000			25–40	32	0.199	7.2×10^{-6}
Powdiron 61–1C (90 Fe, 10 Cu)..... Heavy duty parts	30,000	140,000	20,000	60,000	17,000			60–90	25	0.221	7.7×10^{-6}
Powdiron 51–1 (100 Fe)..... Special parts	12,000	130,000	20,000	50,000	22,000			35–50	25	0.214	6.8×10^{-6}
CHRYSLER CORP. AMPLEX DIV.:											
Oilite Bronze (90 Cu 10 Sn):											
Bearings and Parts.....	12,500	120,000	8,000	75,000	11,000	16,000	5	30	30	0.22	10.5×10^{-6}
Machine Parts Heavy Duty.....	18,000	200,000			20,000	25,000	10	30		0.25	
Machine Parts Maximum Duty.....	40,000	230,000			30,000	35,000	20	60		0.30	
Super-Oilite (75 Fe, 25 Cu):											
Bearings and Parts.....	30,000	198,000	46,000	50,000	30,000	47,000	1	45	25	0.23	7.7×10^{-6}
Machine Parts Heavy Duty.....	35,000	190,000			35,000	50,000	2	60		0.25	
Machine Parts Maximum Duty.....	45,000	250,000			40,000	55,000	2	90		0.256	
Iron Oilite (100 Fe):											
Bearings and Parts.....	15,000	130,000	20,000	50,000	22,000	40,000	1	40	30	0.22	6×10^{-6}
Machine Parts Heavy Duty.....	30,000	120,000			30,000	50,000	2	70		0.230	6.8×10^{-6}
Machine Parts Maximum Duty.....	35,000	150,000			35,000	55,000	2	90		0.24	7.0×10^{-6}
KEYSTONE CARBON CO.:											
Selflube Bronze (90 Cu, 10 Sn).....	14,000			45,000	11,000†				24	0.222	
Selflube Iron (95 Fe, 5 Cu).....	16,000			50,000	30,000†				29	0.195	
Selflube Iron (90 Fe, 10 Cu).....	40,000				50,000†				24	0.212	
MORAINE PRODUCTS DIV., GENERAL MOTORS:											
Durex Iron (88 Fe, 12 Cu).....	25,000		15,000	50,000	20–25,000		Nominal	60–90	20–30	0.20–0.22	$6.5–7\times10^{-6}$
Durex Iron (100 Fe).....	20–35,000				10–15,000		3–12	35–70	10–25	0.21–0.24	$6.5–7\times10^{-6}$
Durex Bronze (89 Cu, 10 Sn).....	12,000		7,500	50,000	11,000			25–40	20–30	0.22–0.25	10×10^{-6}
Durex Bronze (95 Cu, 5 Sn).....	30–40,000				12–20,000		5–10	65–100		0.29	
UNITED STATES GRAPHITE CO.:											
Grade 61 (90 Cu, 10 Sn).....	21,000		7,000	50,000	14,000	18,000			20–25	0.237	9.7×10^{-5}
Grade 81 (90 Cu, 10 Sn)..... Slight graphite addition	14,000		6,000	50,000	9,000	13,000			20–30	0.223	9.7×10^{-5}
Grade 86 (85 Fe, 15 Cu)..... Slight graphite addition	20,000		15,000	50,000	16,000	24,000			15–20	0.210	7.1×10^{-5}
Grade 139–U (100 Fe).....	10,000		10,000	50,000	14,000	18,000			20–25	0.199	6.8×10^{-5}

* Data based on standard ASTM specimens
† In Compression — 2 percent



Dense iron-copper components of a control mechanism for aircraft. The gear on the hub must slidably engage the internal gear in the plate at any desired indexing position. The hexagon hole and bore in the hub are concentric with each other but eccentric with the hub by the molding process. Both parts are made of a material that possesses maximum strength required





Serving as a bearing and a spacer in the track of a heavy-duty mobile unit, this piece is made from self-lubricating iron-copper powder metal. Spline dimensions are held to 0.002 in. limit. The splines make a square corner with the flange, a feature that would be impossible to obtain by any other commercial production process

ting die under very close control and compacted to approximately one-third the powder volume, and the briquetting process is controlled for the desired degree of porosity in the case of bearings or density in the case of solid parts; 4. strength is developed in the fragile "green" compact by sintering, which is a heat-treating process designed to obtain an alloying or welding action; 5. The part is sized by pressing; 6. supplementary heat-treatments or processing of specialized nature may be added to develop additional properties.

The compact is formed either by one punch entering a die, or by two opposed punches in an effort to minimize porosity at the center of the part. Thus holes, recesses and splines are customarily limited to those made by punch travel. Holes or recesses that must be made by side-operating cores are particularly feasible. Most powdered metal parts are cylindrical, flat or dished shapes. No draft need be allowed on holes or recesses made by punch travel, and the height relationship of elements with respect to the base can be held to a few thousandths.

For almost all cylindrical parts the tolerance on the outside and inside dimensions can be held to ±0.0005 in. for items up to 2 in. in diameter, and to ±0.001 in. for parts from 2 to 5 in. in diameter. Height tolerances cannot be held as close, namely ±0.005 in. for the entire range. These figures are considered by several firms as beyond commercial limits and attainable only by special control over the production processes.

Powdered metal parts are not a cure-all for engineering and war-shortage problems but their application is worth consideration.

* Data based on standard ASTM specimens
† In Compression — 2 percent

Grade 139–U (100 Fe) .....

WARTIME DESIGNS

B-24 Output Boosted Hundredfold By Simple Engineering Changes

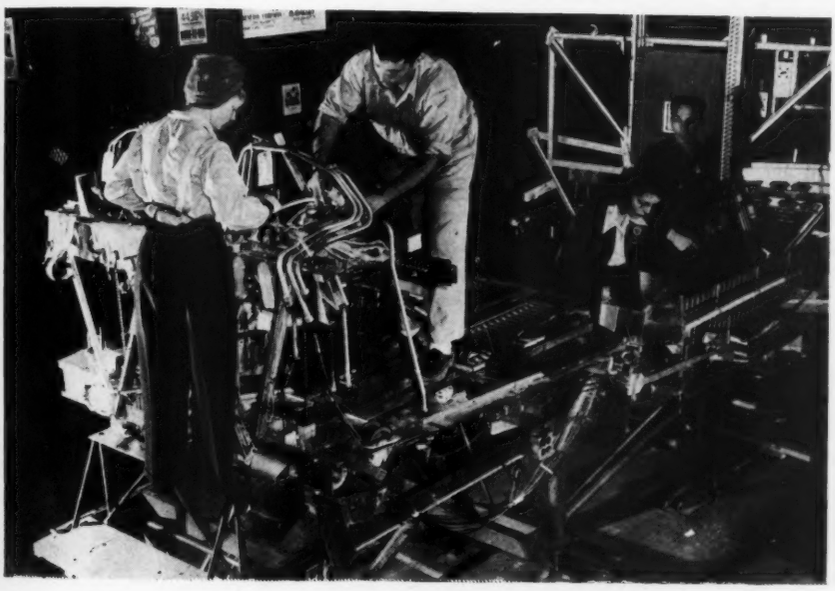
BECAUSE of close quarters a crew of only six could work inside the fuselage nose section of the Liberator B-24 to install and connect the innumerable instruments, radio equipment, pilot controls, engine controls, wires and tubings. It took 50 working days to complete one fuselage nose section. Then came Pearl Harbor! Consolidated-Vultee engineers were given the job of breaking this production bottleneck and they did it.

They now build the nose shells as before but omit the rivets along four lines of cleavage that divide the assembly into six components—bottom, two sides, pilot's floor, and two roof sections. The unit is carried by crane to installation-assembly lines, separated into its six components and each section then starts simultaneously down separate mechanized lines.

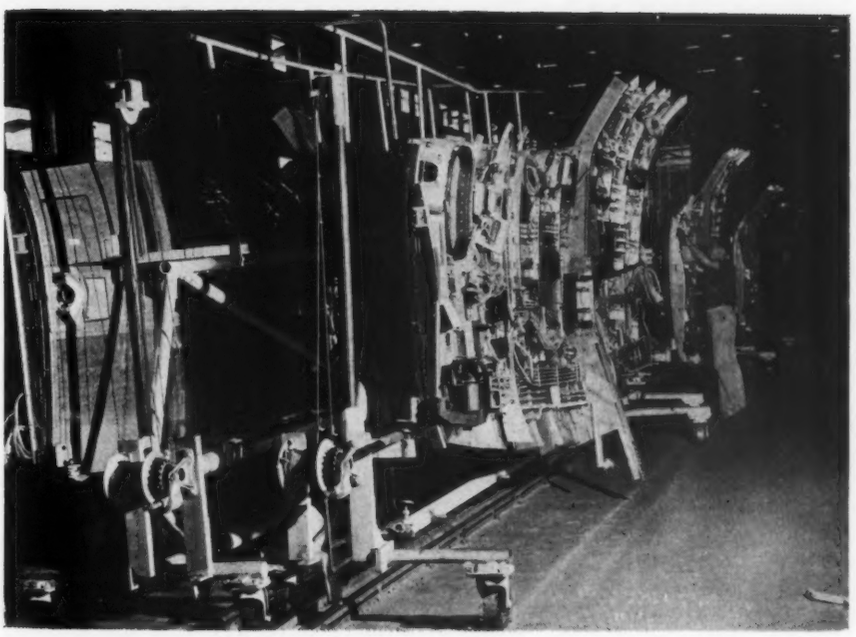
Relatively few changes in wiring and tubing arrangements made possible the new assembly method. Results are amazing. Today only one-third of the workers previously required turn out more than 33 times as many completed nose sections as were produced a few months ago.

Shell of the nose fuselage section is assembled in stationary bucks, lifted out of the fixture by the overhead crane and carried to the disassembly station. By cutting out a few rivets, the shell is parted into six segments —two side panels, bottom panel, two sections of top panel and flight deck.

Bottom and side panels are sent down "clean-up" lines for driving such rivets and the installation of such instrument brackets as were difficult to reach in the stationary assembly bucks. The same work is done on the flight deck and the two top panel segments at fixed stations.

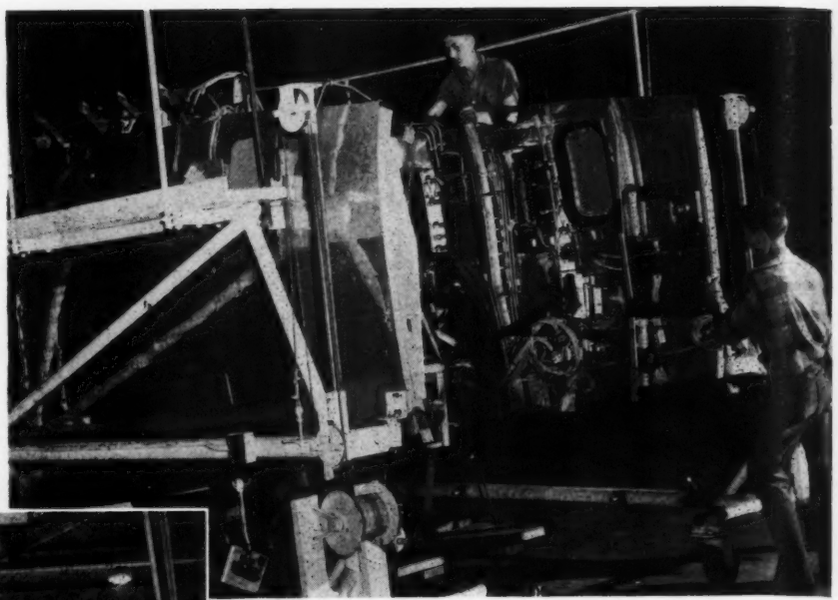


Maze of wiring, tubing and control cables is installed on the flight deck after disassembly and "clean-up." Because everything is "in the open" instead of in the confines of the shell, more people can work at it and the installations are then made faster.



Side panels are held vertically in fixtures that move on tracks from station to station to receive their quota of instruments, controls, wiring systems and tubing systems.

Sections of the nose fuselage shell leave the primary assembly lines and are reassembled before going to final assembly. The routine of assembly is to "button" the side panels to the flight deck. Then the bottom is fastened in position, followed by the two sections of the top panel.



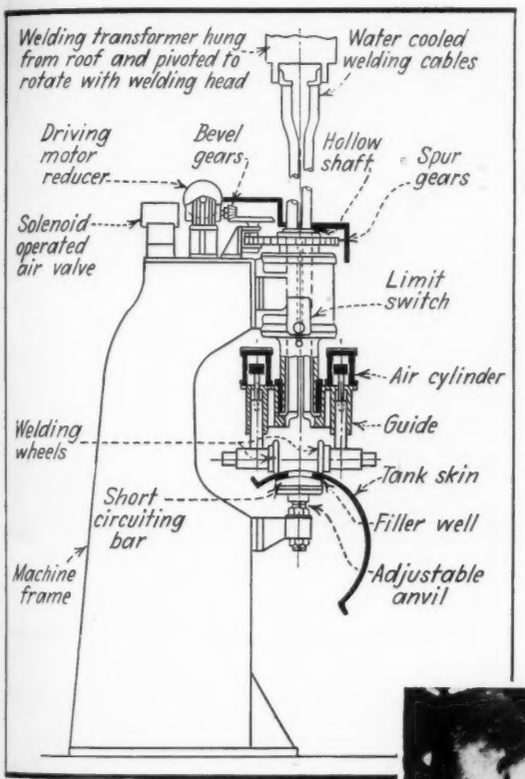
Wiring and tubing that were installed on the various segments are connected at the assembly of the fuselage components. Wires and control cables that are to run to other portions of the plane are coiled and tied temporarily.

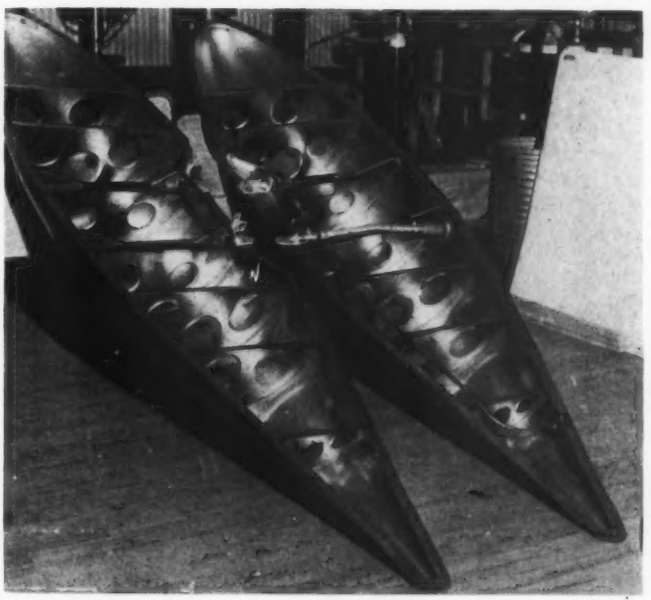
Completed nose fuselage section with its 700,000 parts and rivets, 13,000 ft. of wiring and 2,000 ft. of tubing rolls off the assembly line ready to be dropped into place on the final assembly line. Soon another Liberator B-24 starts on war missions, whose purpose its name bespeaks.

Specially Designed Welding Equipment Assembles Auxiliary Fuel Tanks

STREAMLINED, droppable fuel tanks permit Lockheed P-38's, Vega Ventura bombers and other American aircraft to carry the aerial war right into the backyard of the enemy. Ten feet long and 27 in. maximum diameter, each tank weighs 90 lb. when empty and 1,000 lb. when filled with 165 gal. of gasoline. Two tanks clamped with releasable brackets beneath the wings will about double the normal range of a Lockheed Lightning. When full, they reduce plane speed only 4 percent. Formerly of aluminum, tanks are now welded 1010 steel, 0.024 in. thick.

High production of these tanks was made possible largely through use of special welding equipment conceived by Harry Chiles of the Lockheed Plant Engineering Department, and designed in collaboration with the equipment design group maintained by the company.





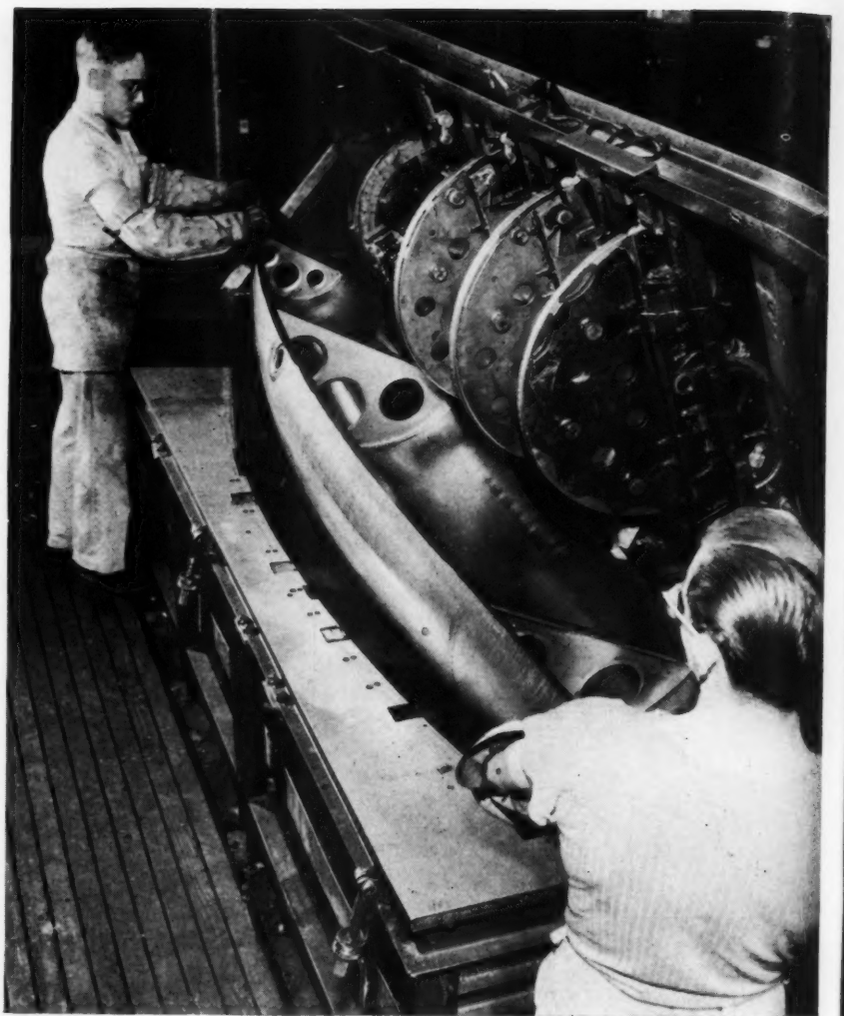
Filler well adaptor assembly is seam welded to the left hand skin. The special series welder used is similar to conventional series seam welders. However, the weld is made on a double-contoured surface having a rise of ¾ in. in 90 deg. of rotation.

Machine is equipped with two air cylinders to which the shaft housings, welding shafts and welding wheels are connected. The two cylinders and welding units, electrically insulated from each other, are bolted to a casting which rotates on a hollow shaft mounted vertically. Water-cooled welding cables connecting the two sides of the transformer secondary to the cast copper shaft housing are brought down through the shaft. The circular copper alloy short-circuiting bar, its upper face contoured to fit the interior of the tank, is mounted horizontally below the two welding wheels.

When the two wheels contact the tank skin, the welding circuit is closed by the short-circuiting bar. Since the welding current flows through the sheets at two points, dual welds are made simultaneously and the 360 deg. of welding are completed in approximately 185 deg. actual rotation of the upper heads.

Special Equipment for Welding Auxiliary Fuel Tanks

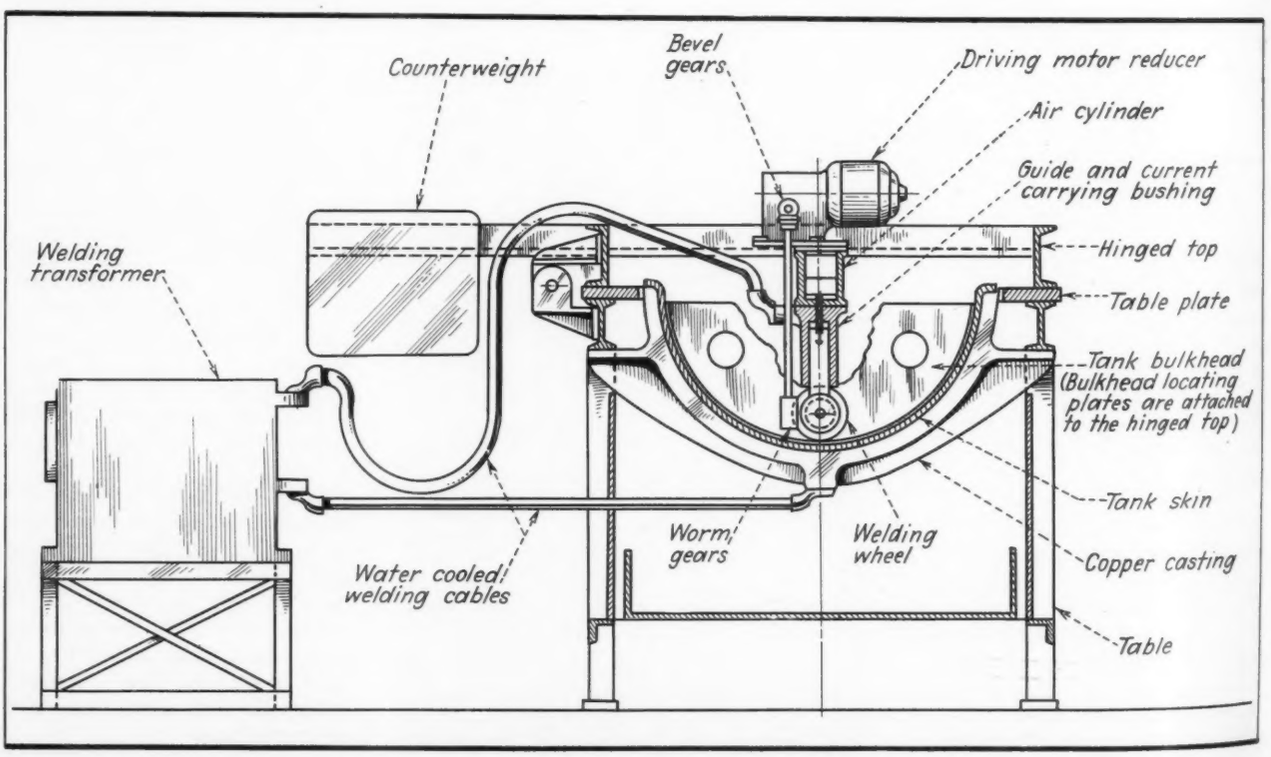
(continued)



Seven bulkheads are welded to the left and right hand skins. This is done with two special semi-automatic welding machines, the first welding three bulkheads in place, the second taking care of the remaining four. Both machines were designed, constructed and installed in 10 weeks. The half shell is placed in the machine where it is supported at the bulkhead stations by copper alloy electrode bars which are machined to fit exactly the outside contour of the pressed-steel tank section. Unique roll-spot welding units, which rotate about the longitudinal axis of the tank, are incorporated in the design. They are fastened to the hinged cover of the fixture that holds the tank sections.

Each of these units consists of a welding wheel and shaft, shaft housing, guide casting, 3 in. diameter by ¾ in. stroke air cylinder, a ½ h.p. driving motor, reducing gear box and the necessary gear train to drive the welding wheel shaft.

Roller spot welds are controlled by a Westinghouse non-synchronous pulsation-weld timer panel with a Weld-o-trol electronic contactor. These timers were modified slightly to secure desired sequence of operations.



Tiny Precision Parts Now Cast Centrifugally

OPTICAL MOUNTINGS and other small intricate components on military instruments are cast centrifugally to ± 0.002 in. tolerances by Morris Kaplan & Sons. The method, developed and patented by T. G. Jungarsen, utilizes flexible molds and is essentially an adaptation of jewelry casting technique. Only machining required is sand-blasting at gating point. Mold cost varies from $50 to $100. Process has been applied only to non-ferrous metals to date. Typical design tolerances held are shown in the drawing below.

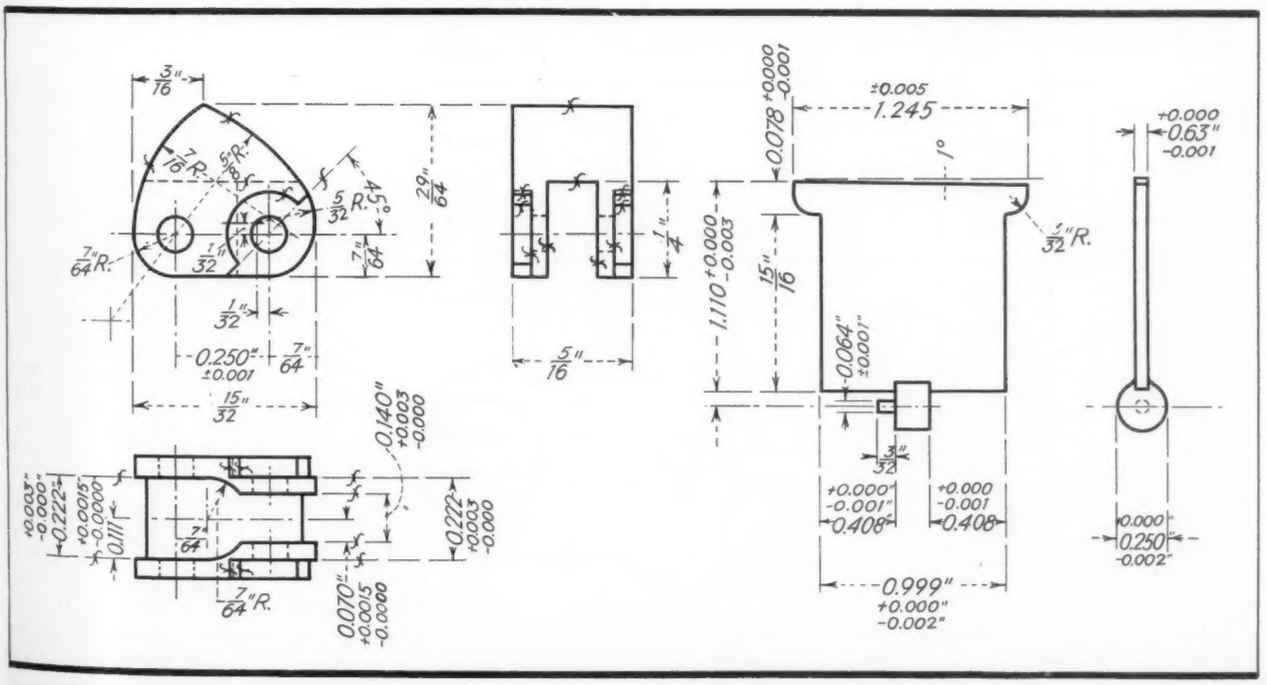
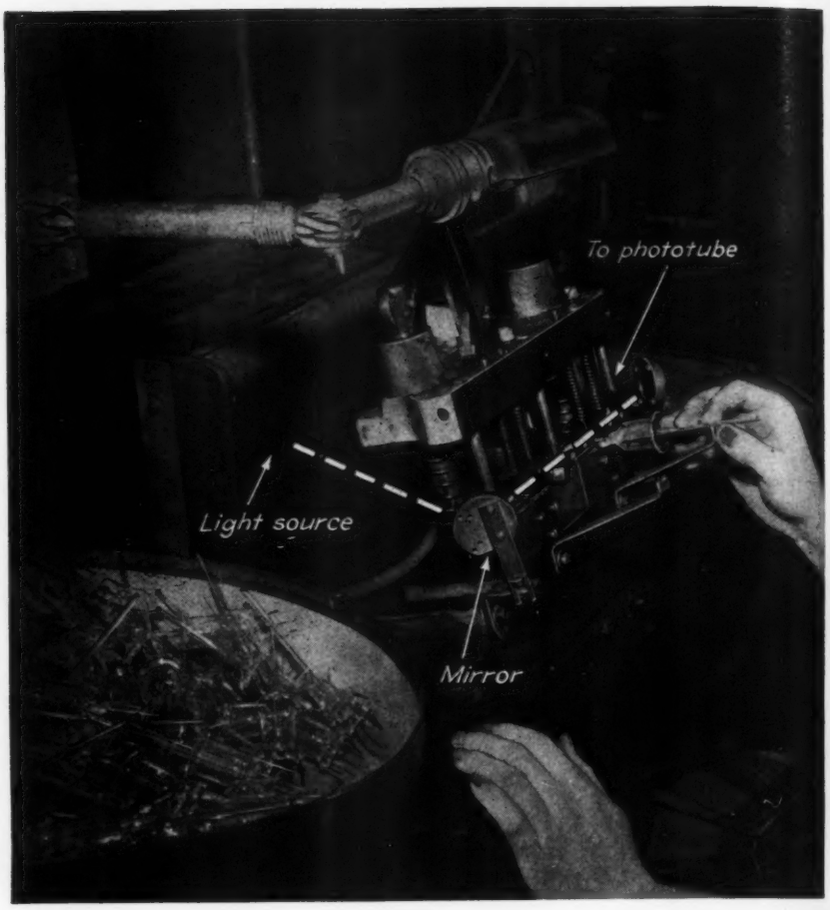
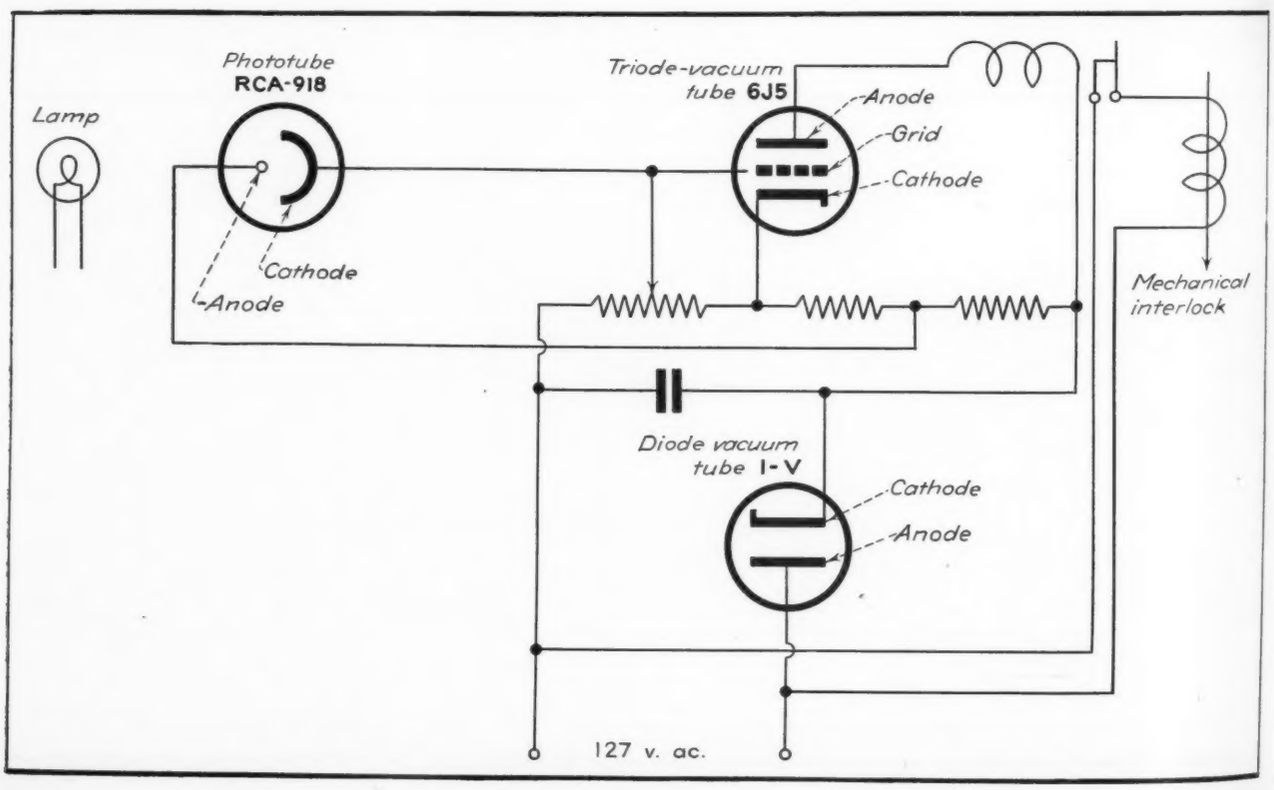


Photo-Electric Eye Guards Against Mishaps

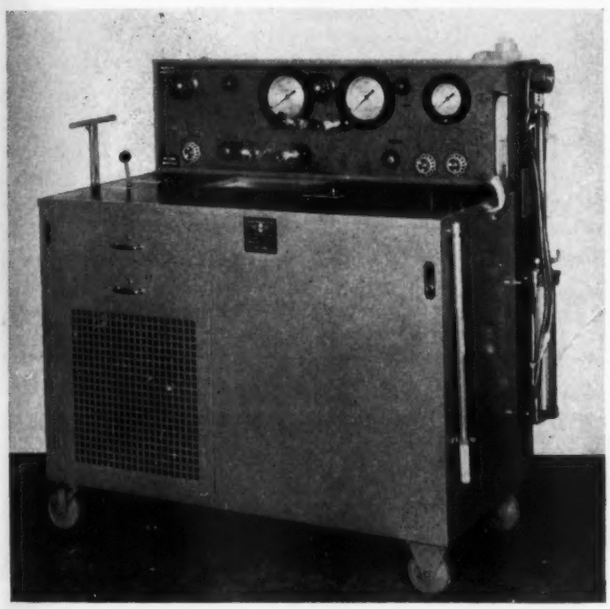


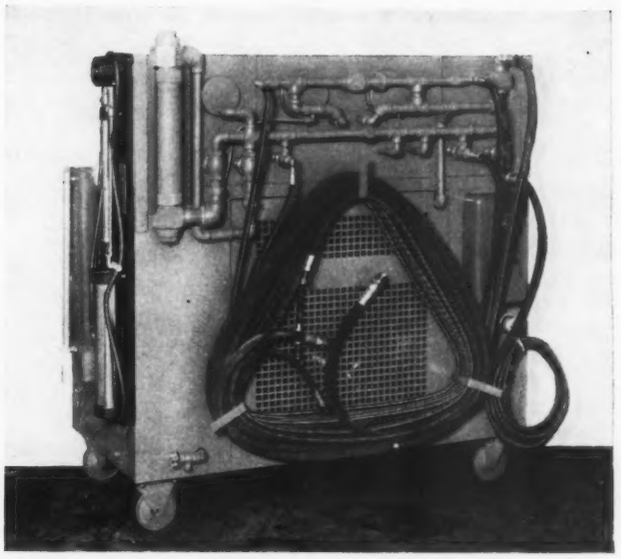
SAFEGUARDING HANDS is the function of a photo-electric device attached to a press used in forming leads for radio tube stems. Two mirrors reflect light from cabinet across front of press. Light beam is broken when operator's hand reaches danger zone and press is halted automatically by an electronic circuit. Failure of any tube or part of the circuit will likewise cause mechanical locking of the press. Electronic unit is portable.



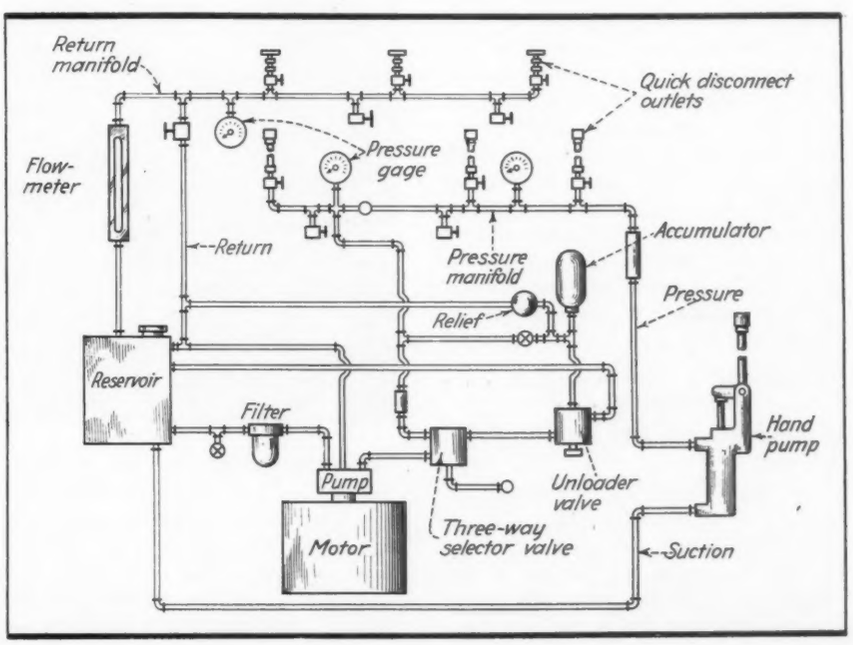
Compact Unit for Testing Military Aircraft Hydraulic Systems

DEVELOPED specifically for checking military aircraft, the Greer hydraulic test stand is adaptable to any existing airplane hydraulic system. It can be used to check the system as a whole, to actuate all hydraulic devices on the plane or to test any hydraulic device separately.





Automatic control and selection of either 1,000 lb. per sq. in. or 1,500 lb. per sq. in. pressure is governed by operation of a clearly marked selector valve. The high pressure system is controlled by a variable volume aircraft pump. An aircraft regulator valve, relief valve, accumulator, and check valve control the 1,000 lb. per sq. in. system and prevent interflow between the systems. A shut off valve allows use of the accumulator as a source of pressure. Pump is powered either with a 7½ hp. electric motor or a 20 hp. constant-speed controlled gasoline engine. Finer control and pressures up to 4,000 lb. per sq. in. can be obtained with a hand pump mounted on the test stand.



Pressure manifold receives flow from the power pump on one end and from the hand pump on the other end. One-half the manifold can be isolated from the other side, so that the power pump can be used to check the brakes or any device at the same time. Three gages are connected to the manifold. Each can be read independently if desired.

A large filter is provided in the unit to assure clean oil when refilling hydraulic systems. An air booster pump, capable of boosting air pressure up to 1,000 lb. per sq. in., is permanently attached to the stand so that airplane shock struts and accumulator can be pressure charged.

WARTIME DESIGN NEWS

PATENT PRONOUNCEMENT:

There is small comfort in the recent report of the National Patent Planning Commission for those who have been poking speculative fingers into the nation's patent system since the days of the Temporary National Economic Committee.

Far from agreeing with those who consider the present system outmoded, the commission proffered a ringing vindication of the existing system and a detailed program for its improvement.

"The (patent) system has accomplished all that the framers of the Constitution intended," the report declares, adding that ". . . the Commission has reached the conclusion that the American system is the best in the world . . . (it) should be adjusted to meet existing conditions without destroying its basic principles."

Probably most shocking to the "junk - it - now - before - it's - too - late" school of patent critics is the commission's flat assertion that "specific inquiries . . . to . . . the War and Navy Departments failed to develop any serious instances in which the patent system has interfered with the prosecution of the present war." Coming from men of such caliber, this statement can only be regarded as a blunt repudiation of those who a year ago were accusing American industries and patent owners of "holding hands with Hitler" and "hamstringing" the nation's war effort through gaping loopholes and inadequacies of the existing system. The report, unfortunately, did not command headlines as striking as those given the charges.

"Stimulated . . . Encouraged . . . Contributed . . ."

The existing system is credited with having:

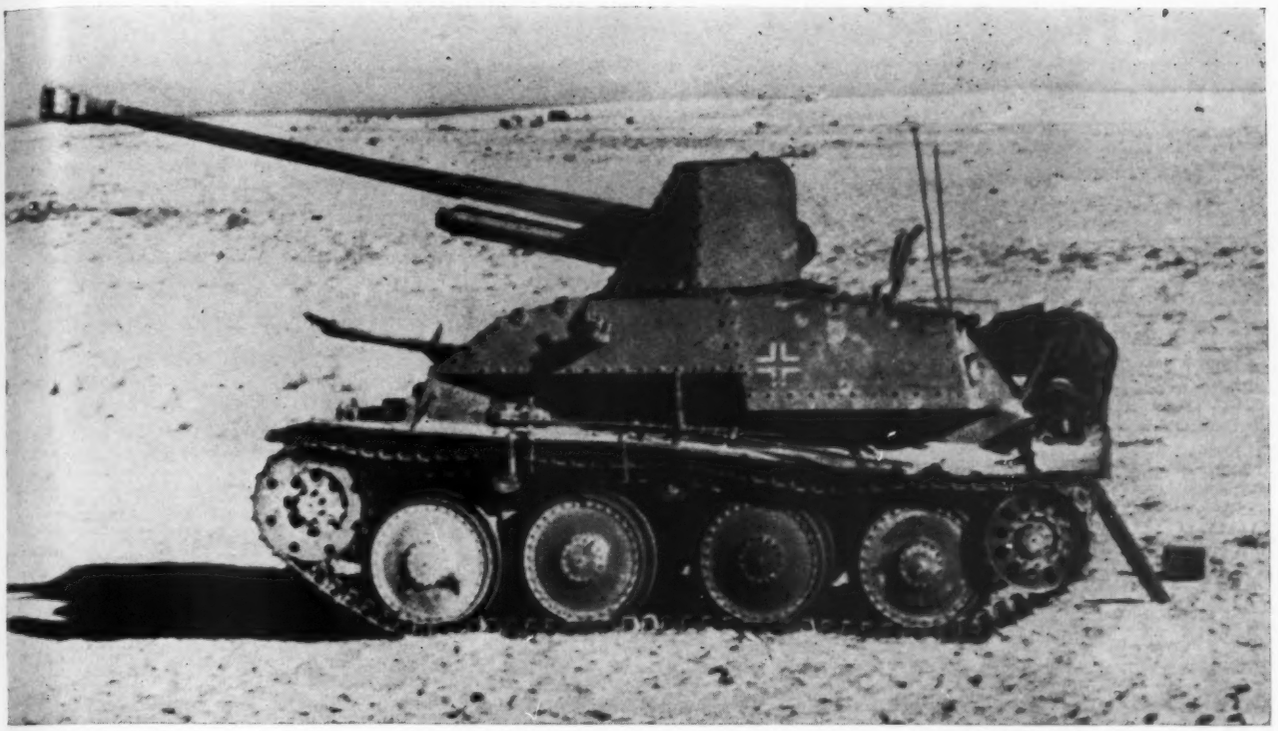
1. "Encouraged and rewarded creativeness and inventiveness . . ."
2. "Stimulated American inventors to originate a major portion of the important industrial and basic inventions of the past 150 years."
3. "Facilitated . . . development and . . . application of new discoveries in the United States to an extent exceeding that of any other country."
4. "Contributed to the achievement of the highest standard of living that any nation has ever enjoyed."
5. "Stimulated creation and development of products and processes necessary to arm the nation and to wage successful war."
6. "Contributed to the improvement of public health and safety."
7. "Operated to protect the individual and small business concerns during formative periods . . ."

The Commission finds no justification for further legislation allowing the government to take or otherwise acquire patents during wartime, holding existing law sufficient. This stand would obviate the necessity for such a bill as S. 2303, (77th Congress) (PRODUCT ENGINEERING, October, 1942, p. 548).

Attributing some of the abuse heaped on the existing system to the use of "secret, improper and even illegal agreements," the Commission recommended that all agreements affecting patents be recorded in the Patent Office where they would be available to public and governmental agencies. Under this provision, ques-

Photo by U. S. Army Signal Corps

Modern design is one of those things the Jap ordnance men read about in American cigarette ads, judging from this picture of captured Japanese guns. The main piece is a 75-mm. regimental mountain gun. Before it is a 37-mm. gun which is vastly inferior in muzzle velocity and fire power to the U. S. 37-mm. piece. Behind the 75 is a 105-mm. gun which has the same steel-shod, wooden wheels as the 37 and 75. These guns compare unfavorably in performance with pieces of U. S. ordnance.



Official Photograph, U.S. Army Air Forces

How the Germans employ the matériel and industrial facilities of countries they overrun is shown in this picture of a German tank captured in North Africa. The tank is a Czech 35 model, the gun a 7.62-cm. Russian piece. The openwork on the mouth of the muzzle is a muzzlebrake, designed to cut down recoil and prevent the gun from splitting. Under the barrel is a recoil tube. Recoil control is a problem in small turret.

tionable practices would be readily detectable. A similar provision was included in most of the bills before the Senate Patents Committee during the 1942 hearings.

No Compulsory Licensing

Compulsory licensing, a fetish of the reformers, was rejected as "not advantageous" to our system. The Commission did recommend, however, "to remove any possible doubt on the subject," that the law be amended to provide that "in a suit for infringement, the patent owner shall be limited to reasonable compensation, without prohibiting the use of the patented invention, wherever the court finds that the particular use of the invention in controversy is necessary to the national defense or required by the public health or safety."

The Commission also recommended that the Patent Commissioner be empowered to determine, in advance of litigation, whether a patented invention is in the province of national defense, public health or safety.

Patent Cancellation

"One of the most serious weaknesses of our present system" is the Patent Office's inability to withdraw or cancel a patent once it has been issued, the Commission found. To remedy this, the Commission proposed that the public be allowed, within six months of the granting of a patent, to challenge validity before the Patent Office. Failure of such challenge to appear would not impair a subsequent infringement suit.

Patterned generally after the British system of "licenses of right" is the Commission's proposal that the Patent Office maintain a public register in which any patentee desirous of licensing his patent may enter the patent and such terms as he may choose to stipulate. When a patentee and a prospective licensee fail to agree on unstated terms, the Commissioner of Patents would set the terms, with the right of appeal provided. The Commission believes that "both individual inventors . . . and the owners of large aggregations of patents would welcome the opportunity of placing their patents on such an official Government register."

The lack of a standard for determining patentability is the "most serious weakness of the present system," the Commission believes. Pointing out that validity of patents is determined now, on non-standard criteria, by the Patent Office, the district courts, the courts of appeal and the Supreme Court, the Commission finds "an ever-widening gulf" between decisions of the Patent Office and of various courts passing upon these decisions.

"No other feature of our law is more destructive to the purpose of the patent system than this existing uncertainty as to the validity of a patent," the Commission asserted. "The admonition is frequently heard that there should be 'fewer and better' patents, an impossible accomplishment so long as the present divergence of standards . . . obtains. . . . The present confusion threatens the usefulness of the whole patent system and calls for an immediate and effective remedy.

"A promising improvement would be for Congress, by legislative enactment, to lay down a reasonable, understandable test by which inventions shall be judged both from the standpoint of the grant of the patent and the validity of the patent therefore. The Commission therefore recommends the enactment of a declaration of policy that patentability shall be determined objectively by the nature of the contribution to the advancement of the art, and not subjectively by the nature of the process by

Official Photograph, U.S. Army Air Force

First the U. S. Army saw of this half-trac motorcycle, used by the Germans as an ammunition carrier, was when it was captured in North Africa. The running gear looks cumbersome for a vehicle of this size. The two outer wheels appear to be stampings. The front wheel fork appears to be of different construction than that used on the standard German motorcycle (PRODUCT ENGINEERING, May, 1943, p. 257).

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which the invention may have been accomplished."

When such a standard of patentability has been established, the Commission admonishes, it must be followed uniformly from the Patent Office to the Supreme Court. Therefore, the Commission recommended that whenever the validity of a patent be attacked in an infringement suit, the record be certified to the Patent Office for a report on the patent's validity, such report to consider any previously unknown facts and to be advisory only.

To end finally the confusion over patent grants and validity, the Commission finds it "imperative" that a single court of appeals replace the present Circuit Courts of Appeals as the intervening stage between Federal District and Supreme Courts. It recommends the Court of Customs and Patent Appeals as this single tribunal on the basis of its experience with patent cases.

Striking at the practice of delaying patent applications and adding thereby to the life of patent protection, the Commission recommends that no patent monopoly be allowed to extend more than 20 years beyond the date of filing in the Patent Office. Where three years or less expired between the filing and granting dates, the life of the patent would be 17 years. Where more than three years elapsed, the amount of time over three years would be deducted from the 17-year life span, unless the delay beyond three years were not the fault of the patentee.

A recommendation of interest principally to attorneys was that the Court of Customs and Patent Appeals be given exclusive jurisdiction of appeals from the refusal of patents.

Future Reports Promised

The Commission promised further reports. It is now studying policies covering inventions by federal employees, agents and contractors and covering the control and use of patents owned by the federal government.

It is also studying the final directive of the executive order which established the Commission, namely "what method and plans might be developed to promote inventions and discoveries which will increase commerce, provide employment and fully utilize expanded defense industrial facilities during normal times."

Members of the commission are Dr. Charles F. Kettering, vice-president of General Motors, chairman, representing science; Chester Davis, ex-War Food Administrator, representing agriculture; Owen D. Young, of General Electric, representing industry; Edward F. McGrady, of RCA Manufacturing Co., representing labor; and Francis P. Gaines, president of Washington and Lee University, representing consumers. Patent Commissioner Conway Coe is executive secretary.

MATERIALS:

Lead, which has been in and out of the critical materials list for months, is going in again. Lead production faces a decline due principally to manpower shortages. The large stockpiles which presented an easy lead picture recently are now smaller.

Softwood plywood manufactured in Washington, Oregon and California is under complete allocation control under Order L-150, as amended. The order controls production as completely as allocation, and deliveries may be made only according to schedule, irrespective of priority ratings.

Prepare Now for Post-War Era

POST-WAR PLANNING has begun to receive major attention, and rightly so. The degree of effectiveness of that planning will be a major factor determining the course of future economic development. It is not strictly post-war planning because development of the post-war economic era will begin months before the war is over. In fact, American manufacturers will soon be called upon to furnish in large quantities goods to be used in peaceful pursuits.

With the Second Front already under way, it will not be long before the forces of the United Nations begin rolling back the Nazi hordes out of the territories they now occupy. Lloyds of London is giving good odds that before the freshets of spring rains come tumbling down the mountains of Jugoslavia, Albania, Greece and other occupied countries, the mythical supermen will have been driven out, at least to a considerable extent. Of the enemy countries, Italy's immediate future is a foregone conclusion; her days of Nazi occupation and Fascist domination are numbered.

Regardless of the measure of Nazi defeat within the next eight months, it is well nigh inevitable that by next spring hundreds of thousands of peasants released from bondage will be chafing to restore their farm soil to productivity. They will need farm machinery, tractors, seeds and other supplies.

Soon millions of workmen will be crying aloud for the opportunity to return to factories and start making the products needed to replace those destroyed—railroad rolling stock, street cars, buses, electrical and plumbing supplies, machinery and equipment. Before many men can be put to manufacturing peacetime products in the devastated countries of Europe, machine tools and manufacturing equipment will have to be furnished to replace the destroyed production machinery.

It will not be possible for Europe to become substantially self-supporting within a reasonable period after hostilities end unless the United States of America quickly furnishes enough machinery, equipment and supplies for the liberated countries to launch a rehabilitation program that will be vigorous from the start. Nor can there be a sustained period of economic prosperity or social well being in the United States of America if European countries are allowed to remain in a state of ruin bordering on chaos.

Financial arrangements by which impoverished Europe can purchase essential materials and equipment from the United States will undoubtedly be worked out in spite of all difficulties. Industry's responsibility is to be prepared to swing rapidly at any moment into production of peacetime goods and machinery required for the rehabilitation of Europe.

Little has been said or written about this phase of the immediate future. A few business leaders have given it serious thought and have expressed themselves on the subject. If any plans are being developed to handle this problem, either by the federal government or industry, such plans are not being given much publicity. One must assume that more can be done, especially on the political side, to assure ravaged Europe a quick return to civilized living. There is little time left to do the planning required.

G. F. Nordenholt

Unground Bearings Used in Aircraft Design

WALTER H. KORFF
Senior Design Engineer, Critical Material Group, Lockheed Aircraft Corporation

Differences between the unground and ground types of ball bearings are summarized. Limitations and advantages are given for the unground type so that its use will be confined to advantageous applications. The design engineers is given data regarding the proper use of the bearings, and is shown how use of unground bearings reduce cost. Principal standard aircraft designations are included

UNGROUND ball bearings have been the means of relieving a bottleneck in the aircraft industry, have reduced costs, and have speeded delivery time for the bearings. Conditions were such that the Army Air Force requested aircraft manufacturers to eliminate ball bearings and thereby ease the bearing situation.

When we reviewed our requirements, we found that aircraft ball bearings are classified and AN-approved as Series I and Series II, both ground bearings. Unground bearings are not classified for aircraft applications and do not exist in aircraft standards, although they are used to a considerable extent. In order to designate such bearings, as distinguished from ground bearings,

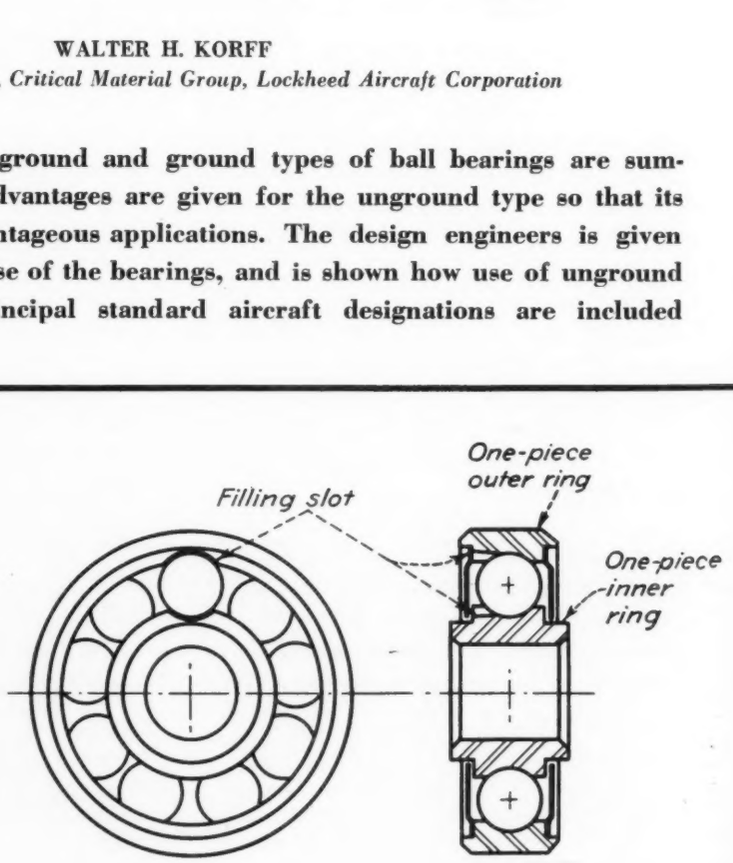


Fig. 1 – Series I type bearing

Walter Seidel of Precision Bearings, Inc., classified the unground bearings as Series III. This classification has no official standing.

The Series I type bearing, made in all types and sizes, has a one-piece inner ring and a one-piece outer ring; internal tolerances of ball to raceways are close, resulting in minimum wobble; raceways are ground, polished, and lapped to provide exceptionally smooth and accurate grooves in which the balls roll. Smooth, accurate raceways are absolutely essential for the proper operation of self-aligning bearings. Rings are made of high carbon chrome alloy steel, S.A.E. No. 52100, and are through hardened.

In order for the Series I type bearings to have the maximum number of balls, the last few are "snapped" through a filling slot. The filling slot must be made accurately so that the balls will not come out during normal operation and yet permit assembly of the bearing with the maximum number of balls, without damaging the raceways. The filling slot has the advantage of permitting the maximum number of balls in a bearing that has inner and outer rings of single piece construction. The disadvantages are that it causes a reduction in thrust capacity, which seldom is critical, and increases bearing cost. The Series I is AN-approved without reservation.

The Series II type of bearing has a one-piece outer ring, a three-piece inner ring, raceways are machined and ground, and internal tolerances are more liberal than in Series I bearings. The rings, like Series I, are of No. 52100 steel.

Since the Series II uses a split inner ring, no filling slot is required. The bearing is assembled on automatic machinery. The Series II bearing is AN-approved for use without reservation, and carries the same load ratings as the Series I classification.

The Series III bearing has a split inner ring which is either a three-piece design or a two-piece design. The raceways are machined only, not ground. Internal tolerances are more liberal than in Series I. The material is usually S.A.E. No. 52100 steel although low carbon steel is sometimes used when the application permits. The rings are through-hardened except when low carbon steel is used in which event the rings are case-hardened. Like the Series II, no filling slot is required, assembly being automatic.

Series III bearings may be had with external dimensions and tolerances interchangeable with series I and II and with the O.D. ground. The bore is always broached.

The steel balls used in all three series are identical and are of the highest quality.

Because Series III bearings are new to the industry, Air Corps approval for individual airplane applications should be obtained until a general Air Corps specification is prepared. Individual approval presents no problem as many items are handled that way.

Proper Usage of Series III Bearings

Generally speaking, in applications where wobble is not critical, where vibration is not too severe, where loads are comparatively light, and where speeds are under 2,500 r.p.m. the inexpensive Series III bearing should be used. This type of bearing is new to the aircraft industry and we should proceed cautiously in its applications so that it, like so many other worthwhile products, will not have to suffer an initial setback as a result of improper usage. As we gain in experience, we can eventually utilize Series III bearings to the fullest advantage.

If a Series I or Series II bearing carries a certain load rating, the Series III bearing of the same size should not be used with a load exceeding 90 percent, the capacity of the Series I or II.

At present, it is also believed best to avoid the use of Series III bearings on primary control systems. This decision is in line with established practice in introducing other products and procedures in the aircraft industry, such as spot-welding, sand castings, die castings, and various new fasteners.

Advantages Over Other Types

It may appear that the Series III bearing has such limited usage that it is hardly worth considering. In answer to this, it is interesting to point out that in reviewing the bearing applications on a well known airplane, 60 bearings of Series III type were installed in place of Series I and II. There is an excellent opportunity that in the final analysis, more than 125 bearings of Series III type will be used on this particular airplane. Savings, on the 60 bearings, amount to over $100,000 for the contract. If the usage finally exceeds 125 per ship, the savings will exceed $175,000. Further, many times in making these changes, production was improved as

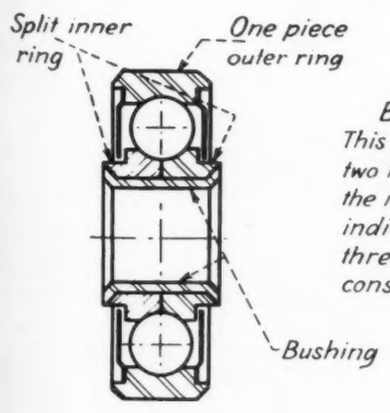


Fig. 2 – Series II type bearing with three-piece inner ring construction

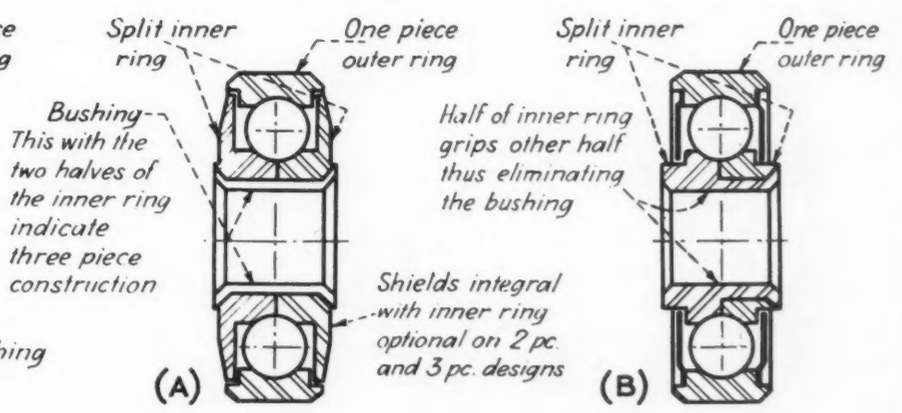

Split inner ring
One piece outer ring
Bushing This with the two halves of the inner ring indicate three piece construction
Shields integral with inner ring optional on 2 pc. and 3 pc. designs
(A)
Split inner ring
One piece outer ring
Half of inner ring grips other half thus eliminating the bushing
(B)

Fig. 3 – (A) Series III type bearing with three-piece construction; (B) Series III type showing two-piece inner-ring construction

GAINS EFFECTED BY CONVERSION TO SERIES III TYPE BEARING

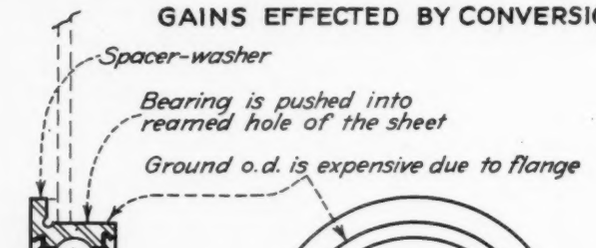
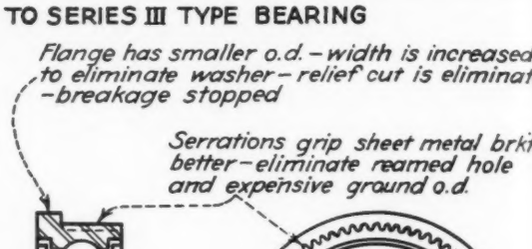

Spacer-washer
Bearing is pushed into reamed hole of the sheet
Ground o.d. is expensive due to flange
Flange is weak due to relief – causes 25% breakage at installation
(A)

FIG. 4


Flange has smaller o.d. – width is increased to eliminate washer – relief cut is eliminated – breakage stopped
Serrations grip sheet metal brkt. better – eliminate reamed hole and expensive ground o.d.
(B)

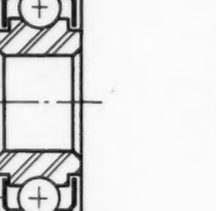


FIG. 5

FIG. 6

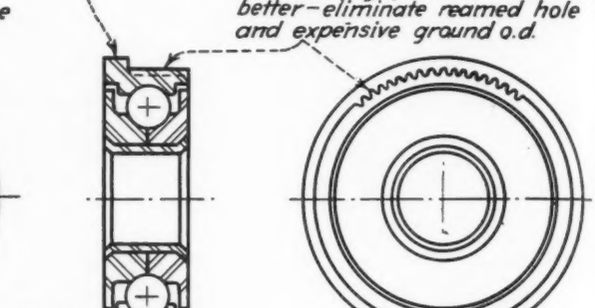
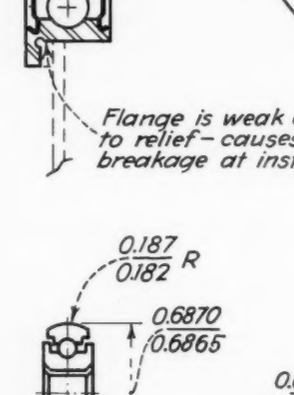
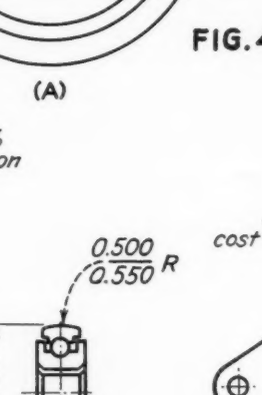

This plate is machined from a solid piece of bar stock to obtain the integral stub shaft; cost – $2.30 each
Shim plate cost $0.06 (est.)
K10A bearing – cost $0.60
Torque tube
(A)
(B)

FIG. 7





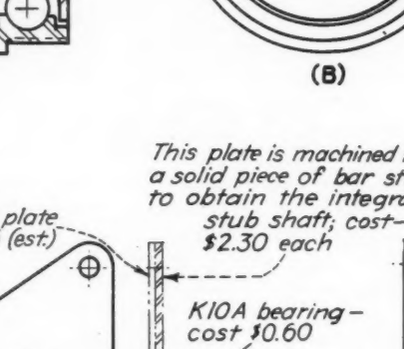


FIG. 10

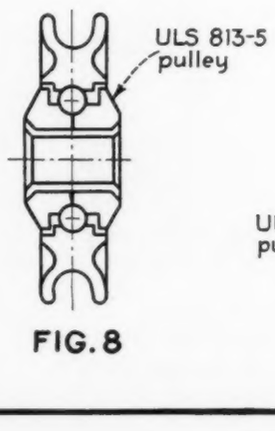


FIG. 8

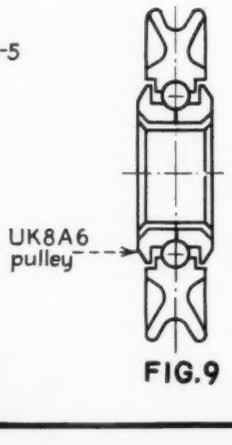


FIG. 9

SOME FEATURES THAT MAY BE INCORPORATED IN SERIES III BEARING

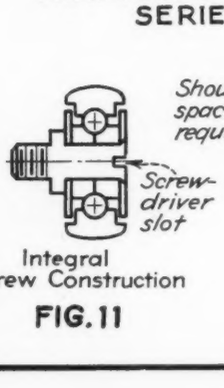


FIG. 11

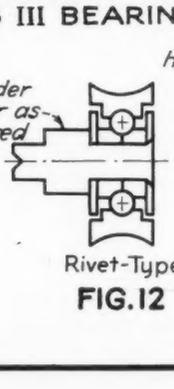


FIG. 12

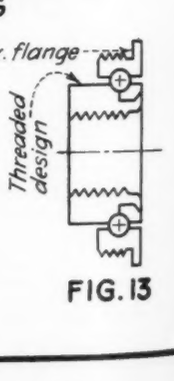


FIG. 13

a result of the simplified design. If Series III bearings are considered in the original design, an even better showing can be made.

For the same size and type of bearing, the Series III costs approximately half that of a Series I. There are a few instances where the Series III cost less than a bushing, making possible costs lower than a bushing, with the anti-friction characteristics and permanent lubrication of the ball bearing.

Series III bearings also have advantages other than cost. The internal looseness can be used to a definite advantage, in some cases. For satisfactory operation, a *D*, double row, Series I bearing must be installed with not more than about ¼ degree misalignment. For *K*, single row, Series I bearings, about ½ degree misalignment is the maximum permissible. The single row Series III will operate satisfactorily with one degree of misalignment. This is quite important when the bearings are mounted on a common axis, but not a continuous rigid shaft. Oil cooler flap bearings are a good example. These flaps are sheet metal assemblies and the hinge brackets are widely separated. Even if the brackets are jig-aligned, the vibration and air loads are severe enough to cause deformation beyond ½ degree. Series III bearings are good in such cases.

Series III bearings may be designed for specific applications. Shoulders, grooves, flanges, serrations, and unsymmetrical bearing designs may be worked out to simplify an application by eliminating a housing, a stamping, or a difficult assembly. Since the bearings are manufactured on automatic machinery, tool and die costs are not involved. Such special designs are practical on relatively short production runs, that is, for small lots.

Series III bearings should be considered for secondary applications such as rollers for adjustable cockpit chairs, vertical axis guide rollers for flaps, guide rollers for push rods, internal door locking mechanisms, canopy rollers, battery trays, and controls where play is not critical. The last include controls for emergency valves and pulleys such as for fire-extinguishers, fuel valves, emergency shutters, small secondary pulleys and fairleads, parking brake controls, and armament rollers. The list is by no means complete, but will serve as a starter and, no doubt, other applications will be found.

Table I—Examples of Bearing Callouts

		Bearing Callout Example			
Single Row	*Metal Shielded*	*K*	(AN200)	Heavy Duty	K-4
		K-A	(AN201)	Medium Duty	K-4A
		K-B	(AN202)	Light Duty (Torque Tube Bearings)	K-25B
	Contact Seals	*KF*		Heavy Duty	KF-6
	Felt, Synthetic Rubber, etc., for Side Shields	*KF-A*		Medium Duty	KF-6A
		KF-H		Extra Heavy Duty	KF-4H
		SIK		Light Duty	SIK-6
	Self-Aligning	*KS*	(AN200)	Heavy Duty	KS-4
Double Row	*Metal Shielded*	*D*		Heavy Duty	D4
	Contact Seals	*DF*		Heavy Duty	DF-6
	Self-Aligning	*DS*		Heavy Duty	DS-4

In the bearing callout examples, it will be noted a number has been added. This number indicates the I.D. bore, in sixteenths of an inch, i.e., K-4 indicates single row ¼-in. bore.

Standard Aircraft Designations

Some of the principal standard aircraft designations for ball bearings are listed in Table I. The meanings of the symbols are as follows:

First letter:

K designates single row of balls

D designates double row of balls

The letters SI preceding K or D indicate side shields

Last letter:

A designates medium duty

B designates light duty

H designates extra heavy duty

S designates self-aligning

The letter *F* designates contact seals

Numerals indicate the bearing bore in sixteenths of inches.

The Series I type bearing is made in all designations.

The Series II bearing is made in all *K* sizes and in all *KA* sizes up to and including K12A. It is not manufactured in any other type or sizes.

The Series III follows established aircraft designations, but it adds a prefix "U" to the part number. It can be made in any size and type shown except the torque tube types, the self-aligning types, and the felt or contact seal types. In addition, the specials designed to your own external dimensions are available on very short notice. The Series III bearing, when shielded, is prepacked with grease, Beacon M285 or equal, meeting AN-G3 Specification. The side shields are colored black to indicate the use of the low temperature grease. Laboratory test on the Series III type bearing has shown them to retain the required free turning characteristics at —70 deg. F., —80 deg. F., and —90 deg. F., making them suitable for high-altitude operation.

Standard Versus Special Bearings

A bearing with individual features such as flanges, grooves and shoulders is classed as "special" and as such is frowned upon. Obviously, it must be stocked as a separate item for use on one particular make and model airplane. It cannot be used on any other type of airplane, in sharp contrast to a standard K-4 bearing or an AN210-3A pulley. On the other hand, one must design a casting or complicated bracket into which to put this standard bearing, and then specify ring

Fig. 4—(A) Series I, K8-2 bearings. Unit cost is 96 cents plus 24 cents for breakage or a cost of $1.20 per application. (B) Series III, UK8-1 bearing. Unit cost, 24 cents, showing a saving over old design of 96 cents per unit or $28,280 for the contract. This design eliminated spacer washer, reamed hole in sheet metal bracket, and flange breakage. Fig. 5—Boom door guide roller. Cost for Series I, 49½ cents and for Series III, 22 cents, resulting in a saving of 27½ cents per bearing. Fig. 6—Flap track guide roller. Cost for Series I, 49½ cents, and 22 cents for Series III; 27½ cents saving per bearing. Fig. 7—Pulley integral with outer ring. Cost 30 cents or a saving per unit of 75 cents; saving $18,300 per contract. Fig. 8—Cost of pulley made integral with outer ring, 36 cents; saving of 36 cents per unit or $2,196 per contract. Fig. 9—(A) Bearing support parts. Total cost of bearing, plate and shim, $2.96. (B) Cross-section of bearing support assembly. Cost 52 cents; saving per unit, $2.44, and $14,884 per contract. Fig. 10—Series III Fairfield rollers. (A) (UFL3C6-5) cost 19 cents, savings 32 cents each. (B) (UFL3C3-5) cost 15 cents, savings 21½ cents each. Figs. 11–13—Features that may be incorporated in Series III bearings.

staking to hold the standard bearing. Ring staking specification is standard practice at Lockheed. When the casting or bracket is "ring staked," it can be used only once. If the stake is removed to replace the bearing, no material remains for the next staking operation. Obviously, the designer compromised his design just to use a standard bearing and, moreover, because nothing else was available, had to specify "staking."

A happy solution to this "standard" argument, which is entirely correct and highly important, is this: Use a special only when it will serve a definitely useful purpose, such as to simplify design, save weight, or increase production, and then only when the special bearing could be replaced in the field with a standard bearing and a simple built-up bracket or drilled plate.

The repair job should use a standard bearing and a bracket that could be made in the field without too much difficulty. The special should have a standard diameter bore as for standard bolts, so that the standard bearing will also fit. There should be enough space available around the special bearing to permit the standard bearing and its housing or bracket to be installed. Such design will take advantage of the mass production features of the special, and should it ever be necessary to replace it at a time when spare parts are not immediately available, the job could be done with a standard bearing and a bracket.

We have all heard many times, "the best is none too good in an airplane," and no designer would care to use a bearing that might impair airplane safety. Since the Series III bearing is admittedly not as much a precision type unit as the Series I or II, many may hesitate to use it. However, regardless of this difference, there are numerous applications where the Series III will give the same trouble-free performance and long life as the finest Series I. There are applications where the Series III will serve better than any other type due to its internal looseness and the ease of incorporating special features. In such applications the quality of the Series III is supreme and it naturally then becomes first choice.

Key Units for Causing Tin Plate to Flow on Metal

THESE units include power rectifying tubes, high frequency oscillator tubes, and oscillator tank circuits. D.c. power at 17,000 volts is applied to the vacuum tube oscillators, and the d.c. is converted to a.c. of 200,000 cycles per second frequency. Water cooled copper conductors carry this high frequency current to the induction heating coil that surrounds the tin coated steel strip. The heat causes a smooth flowing of the tin plate on the metal sheet.

Westinghouse Electric & Mfg. Co.

Corrosion Protection For Magnesium Alloys

Fourth of a series of articles based on data and information furnished by American Magnesium Corporation. Various methods are described for protecting magnesium alloys against atmospheric, chemical and galvanic corrosion, including chemical treatments, painting, plating, and insulating materials. Resistance of various alloys to many common corrosive agents is tabulated.

PAST limitations of magnesium centered chiefly around its inability to resist corrosion. The field of applications has been expanded by development of magnesium alloys and protective-coating treatments.

Commercially pure and uncoated magnesium and many of its alloys resist most outdoor atmospheres satisfactorily. Some surface attack of the uniform-etching type occurs but there is no structurally serious corrosion unless moisture is trapped in crevices or low spots.

Marine or seacoast locations induce corrosion and may cause severe attack. For example, two years' exposure to seaboard atmosphere caused a loss in tensile strength of 9 percent in dichromate-treated (AMC Treatment A) ½-in. diameter AM57S test bars, whereas equally long exposure to inland industrial atmosphere resulted in a loss of only 2 percent. Bare 0.064-in. AM3S alloy sheet specimens exposed two years to seaboard atmosphere lost 20 percent, as compared to a loss of 22 percent caused by four years' exposure to inland industrial atmosphere.

Magnesium alloys differ considerably in their resistance to outdoor atmospheres, as shown in Table I. Progress in increasing resistance to corrosion of magnesium alloys is illustrated by a comparison of AM57S and AM-C57S alloys. AM57S is typical of magnesium alloys available until five or six years ago. It is comparatively resistant to inland and seaboard atmospheres, but is rapidly attacked by salt spray, losing half of its tensile strength during eight weeks' exposure. Under the same conditions of test, AM-C57S, a modification of AM57S in which the impurities, iron and nickel, have been reduced to extremely low concentrations, loses only about 10 percent of its tensile strength. Lately, a "C series" of high-purity modifications of several other wrought magnesium alloys (AM-C58S, AM-C74S, AM-C52S) have been developed.

Another example of recent improvements in corrosion resistance is the substitution of zinc-bearing alloys of the AM265 or AM260 type for AM240 alloy in sand and permanent-mold casting work. Whereas bare ½-in. diameter test bars of AM240-T6 alloy, after two years' exposure to seaboard atmosphere, lost 26 percent of their tensile strength, the loss of AM265-T6 alloy under the same conditions was only 5 percent.

Magnesium alloys are ordinarily not subject to intercrystalline corrosion. Where corrosive attack occurs, it proceeds at a relatively uniform rate from the surface without seeking out grain boundaries.

Magnesium alloys resist the action of solutions of many alkaline materials—borates, fluorides, chromates, chromic acid and hydrofluoric acid. Solutions of most of the other mineral acids and their salts are definitely corrosive. The suitability of magnesium for use with a number of the more commonly encountered chemicals is given in Table II. The action of many unlisted substances is also known.

Protective Chemical Treatments

A number of coatings applied by chemical treatment frequently supplemented by paint coats, are available. Characteristics and specifications of chemical coatings are given in Table III. Chrome pickle or dichromate dip (AMC Treatment A), is applied by the mills to most magnesium alloy

Table I—Corrosion Resistance of Magnesium Alloys

Magnesium Alloy	Rating[1]		
	Exposure to Inland Atmosphere	Exposure to Seaboard Atmosphere	Exposure to 3 Percent Salt Spray
CAST			
AM403-C	A	A	A
AM240-C	B	B	B
AM240-T4	C	C	D
AM240-T61	B	B	D
AM260-T4	B	B	B
AM260-T6	B	B	B
AM265-C	A	A	B
AM265-T4	B	B	B
WROUGHT			
AM3S	B+	A	B+
AM52S	B+	B+	B
AM-C52S	B+	A	A
AM57S	C	B	D+
AM-C57S	A	A	A
AM58S	C	B	C
AM-C58S	B+	B+	B+
AM59S	B	B	D
AM-C74S	B+	B+	B+

[1] The rate of corrosion of rating B is roughly twice that of A; C twice that of B; and D twice that of C. Ratings in one column bear no relation to those in another column.

Table II—Action of Some Chemicals on Magnesium Alloys

Recommendations as given here by American Magnesium Corporation are based on practical experience or laboratory experiments and should serve only as a preliminary guide. Difference in service conditions, such as impurities in chemicals, may effect corrosive action. Trial should be made before any substantial new application is undertaken. Sometimes a paint coating permits use of magnesium in contact with materials that might attack the bare metal.

Recommendations apply to 100 percent concentration of reagents unless otherwise indicated. Disapprovals apply to 100 percent concentration of reagents and any concentration in water solutions.

		Magnesium Recommended
Water	Distilled water, < 100 deg. F	Yes
	" " > 100 deg. F	No
	Tap water, sea water, carbonated water, steam, 212 deg. F	No
Acids	Hydrofluoric acid 10 to 50 percent	Yes
	Chromic acid (pure), any concentration	Yes
	Phosphoric acid, any concentration	Trial warranted
	All other acids	No
Metal Salts and Hydroxides	Alkali metal fluorides, carbonates, and hydroxides, any concentration	Yes
	Borax solutions, 1 to 3 percent	Yes
	Cyanides (most), any concentration	Yes
	Chromates and bichromates (most), any concentration	Yes
	Ammonium hydroxide	Trial warranted
	Hydroxides (most), any concentration	Yes
	Permanganates (most), any concentration	Yes
	Phosphates (most), any concentration	Yes
	Sodium silicate, any concentration	Yes
Various Reagents	All metal salts not listed	No
	Mercury	No
	Oxygen	Yes
	Ammonia gas or liquid	Yes
	Fluorine	Yes
	Chlorine	No
	Ink (iron)	No
	Sulphur	Yes
	Carbon monoxide and dioxide	Yes
Alcohols	Butyl	Yes
	Ethyl	Trial warranted
	Methyl	No
Acids	Carbolic acid	Yes
	Other organic acids	No
Oils, Greases, Petroleum Products	Castor oil	Yes
	Vegetable oil (chloride free)	Yes
	Mineral oil (chloride free)	Yes
	Animal oil (acid and chloride free)	Yes
	Tung oil	Yes
	Grease (acid free)	Yes
	Linseed oil	Yes
	Lanolin	Yes
	Asphaltum	Yes
	Tar	Yes
	Turpentine	Yes
	Kerosene	Yes
	Hydraulic brake fluids (most)	Trial warranted
	Benzine	Yes
	Gasoline, Lead Free	Yes
	" Leaded	Trial warranted
Foodstuffs	Foodstuffs of any kind, solid or liquid	No
Various Organic Reagents	Acetone	No
	Acetylene	Yes
	Aniline	Trial warranted
	Carbon tetrachloride	Yes
	Diethylene glycol	Yes
	Diethylene glycol solutions (any concentration)	Trial warranted
	Ethylene glycol	Yes
	Ethylene glycol solutions (any concentration)	Trial warranted
	Gas, illuminating	Yes
	Ink (dye)	Yes
	Rubber	Yes
	Rubber cement	Yes

commodities, such as rough castings, forgings, extrusions and sheet. This coating etches and passivates the magnesium surface. Its functions are to prevent corrosion and retard tarnishing in applications not requiring additional surface protection, or to serve as a base for subsequent application of one of the more resistant coatings or of a paint system, or combinations of both. This treatment is particularly necessary on sand-blasted surfaces, which otherwise show poor corrosion resistance.

Coatings G and H, lately supplemented and partially replaced by K and L, may be considered general-purpose coatings of good protective value. Coatings for special purposes are C for magnesium parts requiring low dielectric strength; E for magnesium die castings; M giving a decorative gray appearance limited to a few machine-wrought magnesium alloys; O, hard coating requiring somewhat elaborate equipment to apply.

Except for coatings O, and to some extent M, the coatings are comparatively soft and are unsuitable for service conditions involving wear and abrasion. They vary in amount of loss of magnesium section resulting from treatment, but most of them do not cause any important dimensional changes. All coatings can be applied to magnesium parts assembled with ferrous or copper alloy inserts, except coatings G, H and K where the pretreatment with hydrofluoric acid will attack most types of inserts. Treatments A, E and L may cause slight etching of the heavy metal inserts.

Coatings G, H, M and O are of comparatively uniform and pleasing appearance and are decorative in interior applications. When applied on assemblies of different magnesium alloys, all coatings lose in effectiveness and in uniformity of appearance. Table IV lists the coatings preferred for machined or formed parts of various magnesium alloys.

Various anodically applied coatings, which have recently been developed and require special electrical equipment, are not considered superior to the best and more readily applied coatings listed in Table IV. In corrosive surroundings, the coating applied by chemical treatment should be supplemented by paint protection.

Painting

Most service conditions require that protective paint coatings be applied to magnesium alloys. Proper surface treatment of magnesium alloys is especially important when they are subjected to severe service conditions. One of the several surface treatments should be employed before any paint is applied. Tests have shown that AMC-G, AMC-L, and AMC-A are the most effective surface preparations for

Table III—Chemical Treatments for Magnesium Alloys

Designation of Treatment AMC	Commercial Name of Coating	Principal Chemicals used in Treatment	Temperature of Bath and Duration of Treatment	Purpose of Coating	Color of Coating	Magnesium alloys Suitable for Coating[1]	Rating of Protective Value (A= Best)	Relative Cost (A= lowest)	Dimensional Change[2]	Effect on Heavy Metal Inserts[3]	Specifications[4] U. S. Army	U. S. Navy	A.M.S.
A	Chrome Pickle or Dichromate Dip	$Na_2Cr_2O_7$, HNO_3	70—150°F., 1 min.	Prevention of tarnishing, paint base	Yellow to brown	All	E	A	minus 0.001 in.	B	98–20010	M-303	2475
C	Chrome-Sulphate	$MgSO_3$, $K_2Cr_2O_7$	150°F., 15 min.	Low dielectric strength	Yellow	All	D	B	none	A	98–20010	M-408	
E	Chrome-Alum	$K_2Cr_2(SO_4)_4$	boiling, 10 min.	Same as A, but specially suitable for die-castings	Dark brown to black	Die-casting alloys	C	B	none	B			
G	Dichromate	HF, $Na_2Cr_2O_7$	boiling, 45 min.	Paint Base	Brown to black[5]	All except AM3S	A	D	none	C	98–20010	M-407	2475
H	Modified Alkali-Chromate	HF, $(NH_4)_2SO_4$, $Na_2Cr_2O_7$, NH_4OH	boiling, 45 min.	Paint base	Brown to black[5]	All except AM3S	B	D	none	C		M-382	
K	Galvanic Anodic	HF, $(NH_4)_2SO_4$, $Na_2Cr_2O_7$, NH_4OH (Galvanic Anodizing)	room, 30 min.	Paint base	Dark gray to black	All	A	D	none	D		M-395	
L	Sealed Chrome Pickle	Treatment A plus sealing in $Na_2Cr_2O_7$	boiling, 30 min.	Paint base	Iridescent red to yellow	All	A	D	minus 0.001 in.	B		M-406	
M	Borax	$Na_2B_4O_7$, $NaHCO_3$	boiling	Decorative[6] comparatively hard	Light gray (5, 6)	AM3S, AM52S, AM-C52S	D	C	none	A			
O	Pressure	NaOH	steam 400°F., 30 min.	Hardest coating available for[6]	Gray to dark brown	All except die-castings. Wrought alloys preferred	A[7]	E	plus 0.001 in.	A			

[1] When applied on assemblies of different magnesium alloys, all treatments lose to some extent in effectiveness and in uniformity of appearance.

[2] Approximate. Multiply with 2 for diameters.

[3] Ratings indicate whether treatment may be applied on magnesium parts assembled with brass, bronze or steel inserts. A=has no effect on insert. B=produces slight etch on brass inserts and attacks galvanized inserts. C=pre-treatment with hydrofluoric acid attacks galvanized or cadmium plated inserts; such inserts should, therefore, be assembled after HF treatment. D=same as C; brass inserts are etched slightly.

[4] Suffixes indicating revision currently in force are omitted.

[5] Treatment has some decorative value in interior uses, but requires paint protection for exterior uses, like all other coatings.

[6] May be dyed.

[7] Rating A in atmosphere, E in salt spray.

painting in about the order as named.

Good adhesion is the chief requisite for a priming coat of paint for use on magnesium alloys not subjected to severe service conditions. For many applications, the primer must have satisfactory corrosion-inhibiting properties, good resistance to moisture penetration, and good adhesion. Of the pigments tested, zinc chromate has the best corrosion-inhibiting properties on magnesium alloys.

Certain synthetic resin varnishes are satisfactory vehicles of the primer in moisture imperviousness and adhesion. Zinc chromate primer (Army-Navy Specification AN-TT-P-656) has such qualities. It dries quickly but can only be applied by spraying. Greater durability can be achieved through the use of varnishes of moderate oil length (20 to 25 gallons of oil to 100 pounds of resin) made with the so-called 100-percent phenolic resins. Primers made with vehicles

Table IV—Chemical Treatments Recommended for Finished Formed and Machined Magnesium Alloy Structural Parts

Commodity	Alloy	Recommended AMC Treatments[2]
Sand or Permanent Mold Castings	All alloys except AM403	G[1]
	AM403	K[1]
Die-Castings	All alloys	E
Extrusions	All alloys except AM3S	G[1]
	AM3S	K[1]
	AM-C57S electrical fittings	C
	AM3S electrical fittings	A[3]
Sheet and Plate	AM-C52S and AM-C57S	G[1]
	AM3S	K[1]
Forgings	All alloys	G[1]

[1] In addition, treatment L is also recommended when a dimensional change of minus 0.001-in. is permissible.

[2] Most desirable treatments considering protective value, paint adherence, stability of dimensions, ease of application and cost.

[3] Modified AMC Treatment A, consisting of short dip of 10 seconds in order to keep dimensional change to minimum.

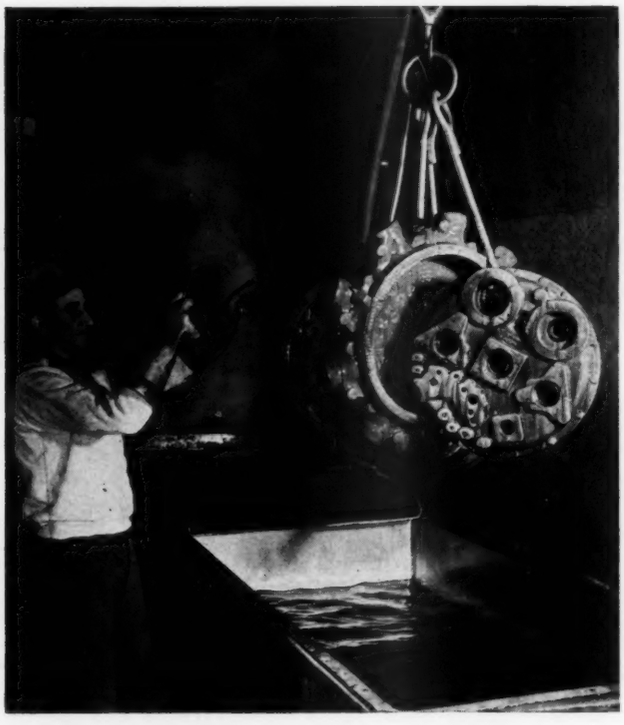
Table V—Summary of Recommended Surface Protection Practice

Service Condition[1]	Primer	Finish
Class 1: General interior (free from corrosive fume and vapor)	One coat of metal primer possessing maximum adherence as shown by test. Primers containing certain of the synthetic resins, especially those of the glycerol-phthalate type, are particularly recommended. Baking usually improves adherence. Under many conditions, priming and painting is unnecessary and one of chemical treatments or of lacquers or wax is satisfactory.	One or two coats of good quality oil paint or enamel. Lacquers may also be satisfactory under certain conditions.
Class 2: Exterior—Inland atmosphere	One coat of metal primer possessing maximum adherence as shown by test. Primers containing certain of the synthetic resins, especially those of the glycerol-phthalate type, are particularly recommended. Baking usually improves adherence. Chemical treatment prior to priming is desirable.	Two coats of enamel characterized by high durability. Vehicles should be of spar varnish or contain synthetic resins of glycerol-phthalate or phenolic type. Clear spar or synthetic resin varnishes pigmented with 2 lb. of standard Albron paste per gallon may be used.[2]
Class 3: Seaboard or other corrosive atmospheres	One coat of zinc chromate primer meeting Army-Navy Specification AN-TT-P-656 or zinc chromate primer made with 100 percent phenolic resin varnish of 20 gallons oil length.[3] Chemical treatment prior to priming is necessary.	Three coats of synthetic resin enamel made with phenolic resin varnish of moderate oil length or three coats of synthetic resin varnish of phenolic type pigmented with 2 lb. of standard Albron paste per gallon. A suitable varnish is either one meeting Army-Navy Specification AN-TT-V-118 or a phenolic resin varnish of 20 gallons oil length.[3] For best results bake each coat 1 hour at 225 to 250 deg. F.

[1] In Class 1 and in most Class 2 service conditions, paint protection is for maintaining appearance, but under certain unusual Class 2 conditions, such as when extremely long service life is required, and under all Class 3 conditions, such protection is necessary to insure preservation of the structural integrity of the part. In the absence of proper surface protection, tarnishing or, in hot and humid atmospheres, light surface oxidation is to be expected under Class 1 conditions, heavy surface oxidation under Class 2 conditions, and pitting under Class 3.

[2] Synthetic resin finishes are improved by baking each coat 1 hour at 225 to 250 deg. F

[3] Length of varnish refers to number of gallons of oil processed with 100 lb. of resin.



Castings are washed in cold water after dichromate treatment

Magnesium sheet is rolled similar to aluminum sheet

of this type do not dry as rapidly as the zinc chromate primer, but can be applied by brush or spray.

The number of finishing coats of paint to be applied over the primer varies with type of service and, to some extent, with the particular alloy used. For adequate protection under severe conditions of use, three finishing coats are recommended. Desired properties in a finishing paint are high resistance to moisture penetration, and good adhesion to the primer. Aluminum paint, made with suitable vehicles, is a most effective finishing

paint. Where other colors are desired, finishing paints pigmented with other materials can be employed if they possess good resistance to moisture penetration and sunlight. Various shades of gray finishes are frequently used.

Certain synthetic resin varnishes are the most effective vehicles for finishing coats. Phenolic resin varnishes of medium oil length (20 to 25 gallons of oil to 100 pounds of resin) are recommended. On surfaces unexposed to salt atmosphere, alkyd type vehicles are satisfactory as they are highly impervious to moisture. Table V summarizes recommended priming and painting practice.

Plating

Metallic coatings of more corrosion-resisting metals such as nickel, copper, and cadmium can be produced on magnesium alloys by electroplating Some of these coatings can be polished to a high luster and withstand indoor and dry atmospheres well. Porosity in the deposits make metal coatings unsuitable if they become wet frequently since galvanic corrosion of the magnesium would result. Application of sprayed-on coatings of the highly corrosion-resistant aluminum alloys of the 56S type, which has a nominal composition 5.2 Mg, 0.1 Mn, 0.1 Cr, has shown promising results.

Stress Corrosion

No stress corrosion failures of commercial magnesium casting alloys AM265 and AM260 or the commonly employed wrought alloy AM3S have been encountered at stresses below yield strength. Certain of the more highly alloyed wrought products may fail by stress corrosion if subjected long to relatively high constant stresses under corrosive conditions. If alloys of the AM52S, AM57S, AM58S, or AM59S types are employed in corrosive environments, high constant stresses should be avoided.

Galvanic Corrosion

In most environments, magnesium has a higher electrolytic solution potential than other structural metals. Joints with most of these metals require protective insulation under conditions conducive to galvanic corrosion as when moisture is present in the joint. Solution potentials of a number of structural alloys, measured in sodium chloride solution, are given in Table VI. Magnesium alloys have relatively high potentials.

Table VI does not indicate quantitatively the amount of corrosive attack. This depends on such factors as formation of surface films and polarization. Corrosion tests made on AM3S and AM240 magnesium alloys coupled with dissimilar metals and exposed to inland industrial atmospheres and on tide water racks on the Florida seacoast resulted in the following ratings, where 1 designates a minimum and 5 a maximum of corrosion of the magnesium member of the couple:

Rating	Dissimilar Alloys* Coupled With Magnesium
1	214, 220, 52S, 56S, 58S aluminum alloys
2	43, 356, 2S, 3S aluminum alloys
3	112, 195, 355, 17S, 24S, Alclad 24S aluminum alloys; galvanized mild steel, phosphate-coated mild steel, cadmium-plated brass 60-40.
4	Cr-Mo (SAE X-4130) steel, cadmium-plated X-4130 steel, stainless steel 18-8; copper, tin bronze, aluminum bronze, brass 60-40, Monel, cast zinc, base alloy (3 Cu, 5 All).
5	Cast iron, cold rolled mild steel, cadmium-plated mild steel.

*Specifications and nominal compositions for above alloys not previously listed:

56S	Navy 43R5 (rivets)	(5.2 Mg, 0.1 Mn, 0.1 Cr)
53S	Navy 47A12	(1.3 Mg, 0.7 Si, 0.25 Cr)
2S	ASTM B25-40-T	(commercially pure aluminum)
214	AN-QQ-A-402	(3.8 Mg)
112	SAE 33	(7.5 Cu, 1.2 Fe, 2.0 Zn)
355	SAE 322	(1.3 Cu, 5.0 Si, 0.5 Mg)

In assemblies with alloys causing the least stimulation of attack, such as aluminum alloys containing magnesium as the principal alloying element and no copper, magnesium requires little or no insulation. The need for protective insulation increases for each of the succeeding groups. If magnesium is used without proper insulation in an exposed assembly with a copper-bearing aluminum alloy such as 17S-T, 24S-T or 195, the magnesium part will not only be galvanically corroded, but will in turn cause severe attack of the aluminum part of the assembly. Rivets used for magnesium assemblies are usually made of aluminum alloys of the 56S type if the joint is subjected to weathering; the same applies to screws and washers where the application permits the use of aluminum and where greatest protection is desired. Galvanic corrosion of the magnesium member in a couple with 56S alloy is not reduced by anodically coating the aluminum member. Steel parts such as bushings, liners, screws, and washers in close contact with magnesium should be galvanized or cadmium-plated.

In these galvanic corrosion tests, AM3S alloy corroded more severely (one number on rating scale), than AM240 alloy. While corresponding differences probably also exist between other magnesium alloys, these are of minor practical significance as far as the recommended insulating practice is concerned. Copper-bearing aluminum alloys should be insulated from magnesium as thoroughly as the heavy metals. The degree of insulation should not be reduced when heavy metals are galvanized or cadmium plated as an added precaution.

Electrolytic conductivity of a corroding solution plays an important part in galvanic corrosion. For instance, the difference between distilled water and seawater is significant in effect on galvanic corrosion.

Insulating materials vary in efficiency. For outdoor exposure, layers of zinc chromate primer or of non-drying sealing compounds, or in more severe exposure, the use of these materials combined with gaskets, as in Fig. 1 are good methods. About the best joint-sealers commercially available are mixtures of zinc chromate, aluminum powder, inert filler, oils and thinner. The use of aluminum paste has been reported for protection of contacting areas between the steel sheets and magnesium housing in electric motors.

The possibility of galvanic corrosion

Table VI—Solution Potentials Measured in Sodium Chloride Solution

Metal or Alloy	Potential in Volts*
Magnesium	−1.73
Magnesium Alloys	
AM3S	−1.71
AM57S	−1.68
AM240-T4	−1.66
AM265-T4	−1.63
Zinc	−1.10
Aluminum Alloys	
220-T4	−0.96
56S-O	−0.87
52S-O	−0.85
2S, 3S, 53S-T, 61S-T, 43	−0.83
356-T4	−0.81
355-T4	−0.78
195-T4	−0.70
17-T, 24S-T	−0.68
Cadmium	−0.82
Mild Steel	−0.67
Lead	−0.55
Tin	−0.49
Brass (60–40); Stainless Steel (18 Cr, 1 Ni)	−0.28
Copper	−0.20
Stainless Steel (18 Cr, 8 Ni)	−0.15
Monel Metal	−0.10
Silver	−0.08
Nickel	−0.07

* Measured in a 1 normal (5.85%) sodium chloride solution containing 0.3% hydrogen peroxide (N/10 Calomel Scale). The values vary somewhat depending on the particular lot of material investigated and on the surface preparation employed.

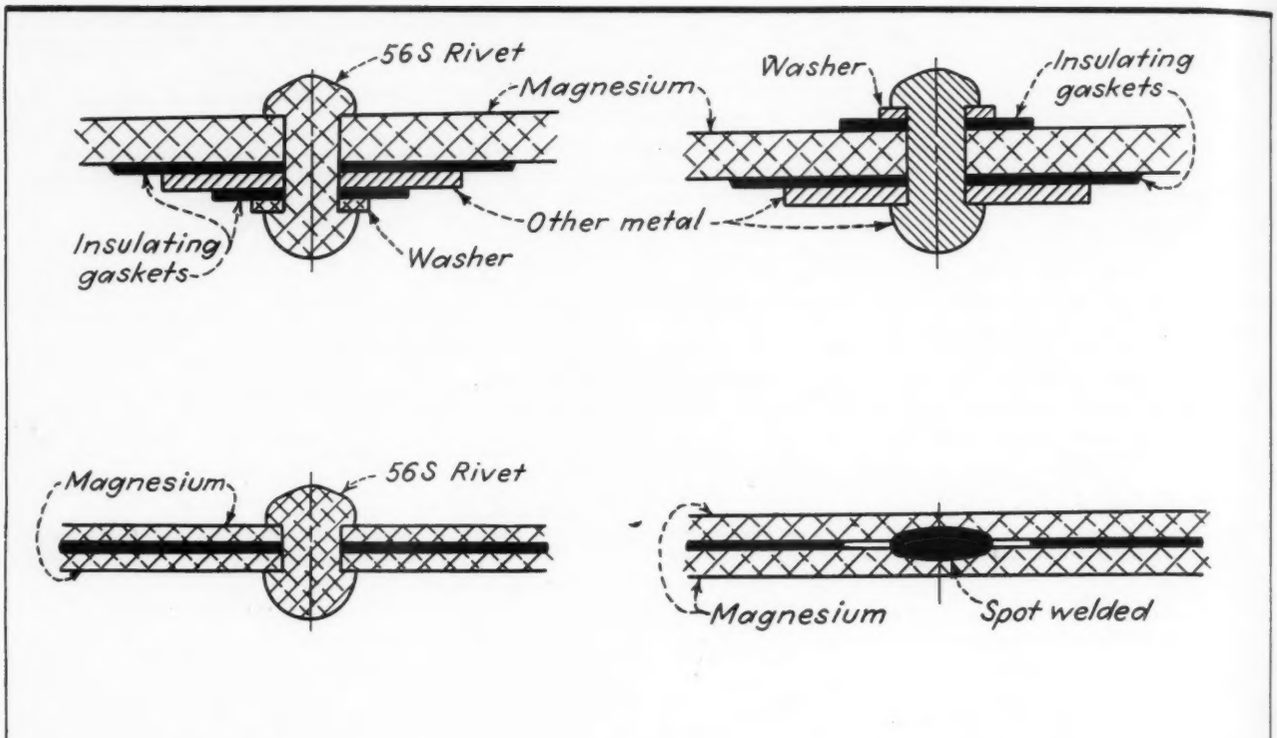


Fig. 1—Joints designed for protection against atmospheric corrosion

is frequently overstressed, but it is necessary to keep it in mind for conditions of intermittent or continuous exposure to moisture.

Faying magnesium surfaces must be primed with zinc chromate and allowed to dry before assembly. It is especially important to protect corners and edges by priming. Joints of magnesium with wood require protective insulation by sealing paints, preferably of the type based on zinc chromate and aluminum powder, in order to prevent corrosive attack by acids or salts leached from the wood.

Prevention of Corrosion by Proper Design

Some corrosion may be avoided by designing to eliminate pockets where moisture may get trapped, or closed containers without ventilation where water may condense. Provision for drainage and ventilation will help greatly, and a coat of zinc chromate primer on the interior and faying surfaces is further protection.

Fretting corrosion has been encountered in highly stressed clamp-type joints between magnesium and other metals when minute relative movements of the parts occur and surface pressures are high. It may be more severe in joints with aluminum than with heavy metals. This type of corrosion is largely prevented by work-hardening the magnesium surface, by the use of soft non-metallic fibre-type inserts, or by inserting steel bushings.

Magnesium aircraft fuel and oil tanks can be protected against sump water by inserting capsules containing a sodium-potassium-fluoride mixture, which passivates the magnesium surface. Water-cooled magnesium alloy crankcases have been prevented from corroding by adding a small percentage of chromates to the water.

The presence of an oil or grease film, as frequently encountered in service, helps to counteract any tendency towards corrosion of any type, and may eliminate the necessity for protective insulation.

Etching Properties

The higher rate of attack of magnesium by nitric acid, in comparison with copper and zinc, is the basis for the use of AM-B52S magnesium alloy sheet for etching plates for photo engraving. A further factor in favor of magnesium is its capacity to retain during etching, the sharp contours of the dots, which are essential for good reproduction of halftones.

EDITOR'S NOTE: Fig. 2, p. 431, July PRODUCT ENGINEERING—word "extrusions" should replace "castings."

Tapered and Stepped Columns Designed for Minimum Weight

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Analysis of the distribution of stress indicates the weight saving possibilities inherent in long columns having varying cross-sections. As a guide for design, hinged end columns with different types and proportions of taper are compared and summarized on a weight basis. A method is also developed for designing and calculating the proportions of constant strength columns.

IN designing many structural members such as engine connecting rods, derrick booms, and aircraft struts to resist compression end loads, weight-saving considerations are important not only to reduce the power required to transport the structure, but also to obtain a minimum of inertia effects caused by sudden acceleration and deceleration.

Weight-saving designs usually take advantage of the fact that in long columns with hinged ends the flexural bending moment is a maximum at a cross-section equidistant from the ends. Also that the bending moment at intermediate cross-sections decreases as the cross-sections approach the ends of the column. Hence, the component of stress set up by flexure in columns of constant cross-section varies from a maximum at the middle of the column to a minimum at the ends. Therefore, it is possible to design a column having tapered ends or decreasing stepped cross-sectional areas that will weigh less than, but be equal in strength to, a column of constant cross-section.

A formula commonly used in working with short columns of constant section is that given by J. B. Johnson, in which

P_{cr} = Critical load on the column, lb.
A = Cross-sectional area, sq. in.
S = Yield point strength of material, lb. per sq. in.
L = Length of column, in.
k = Minimum radius of gyration, in.
C = Constant dependent upon end conditions
E = Modulus of elasticity of the material, lb. per sq. in.

$$P_{cr} = A\,S\left[1 - \frac{S\,(L/k)^2}{4\,C\,\pi^2\,E}\right] \qquad (1)$$

The plot of Equation (1) is a parabola which is tangent to the plot of Euler's equation

$$P_{cr} = \frac{\pi^2\,C\,E\,A}{(L/k)^2} \qquad (2)$$

The value of L/k at which the two curves are tangent, found by equating the failure loads of Equations (1) and (2), is

$$\frac{L}{k} = \sqrt{\frac{2\,C\,\pi^2\,E}{S}} \qquad (3)$$

In design problems the Euler equation may be used when values of L/k are greater than that given by Equation (3), when values of L/k are less than that given by Equation (3) the J. B. Johnson expression may be used. When C equals 1 (hinged ends), E equals 30,000,000 and S equals 40,000 lb. per sq.in., L/k is 122 at the point of tangency. With an alloy steel having a yield point of 120,000 lb. per sq.in., and C equal to 1, the value of L/k drops to 70.5 at the point of tangency.

On this basis the Euler equation and the discussion which follows will apply to a greater range than is usually supposed when high yield point steels are used.

Euler's equation is based upon pure flexure caused by the deflection of the column centerline under the applied load. With

x = Distance measured from end of column
I_x = Moment of inertia of section at a distance x
y = Deflection of center line at distance x
P = Load on column

the moment at any point is Py (see Fig. 1) and the differential equation of the deflection curve is

$$E\,I_x\frac{d^2y}{dx^2} + P\,y = 0 \qquad (4)$$

Since the deflection y at the ends of the column is zero, Equation (4) indicates that the ends are pointed, that is, have a zero moment of inertia. But, obviously, in practice the ends must have a bearing area based upon the compressive strength of the material used and the end load.

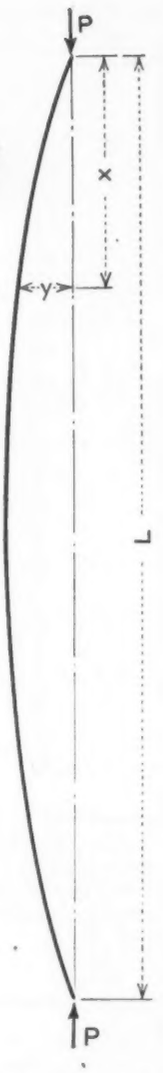


Fig. 1 — Deflection of the center line of a column having hinged ends under applied end load

The solution of Equation (4) for stepped and tapered columns of various proportions and forms has been solved by Dr. A. N. Dinnik and reported by Mr. M. Maletz ("Design of Columns of Varying Cross-Sections," *A.S.M.E. Transactions* APM 51-11, 1929 and APM 54-16, 1932). Dr. Dinnik uses a constant K the value of which depends upon the form and proportions of the taper or step. For a pin ended column of constant section K is π^2. I is the maximum moment of inertia. The critical load for each case is given by

$$P_{cr} = \frac{K\,E\,I}{L^2} \qquad (5)$$

To determine the lightest weight column to support a given load, the cases solved by Dr. Dinnik will be here investigated. The percent saving in

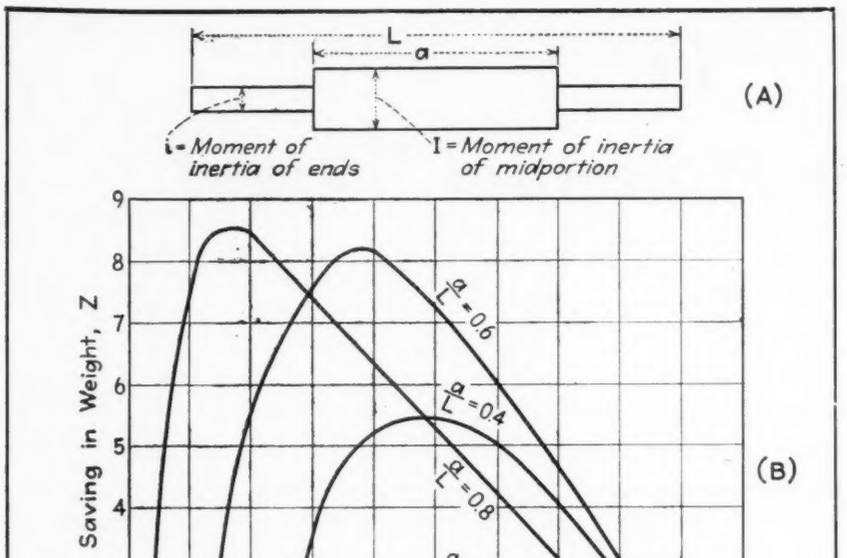
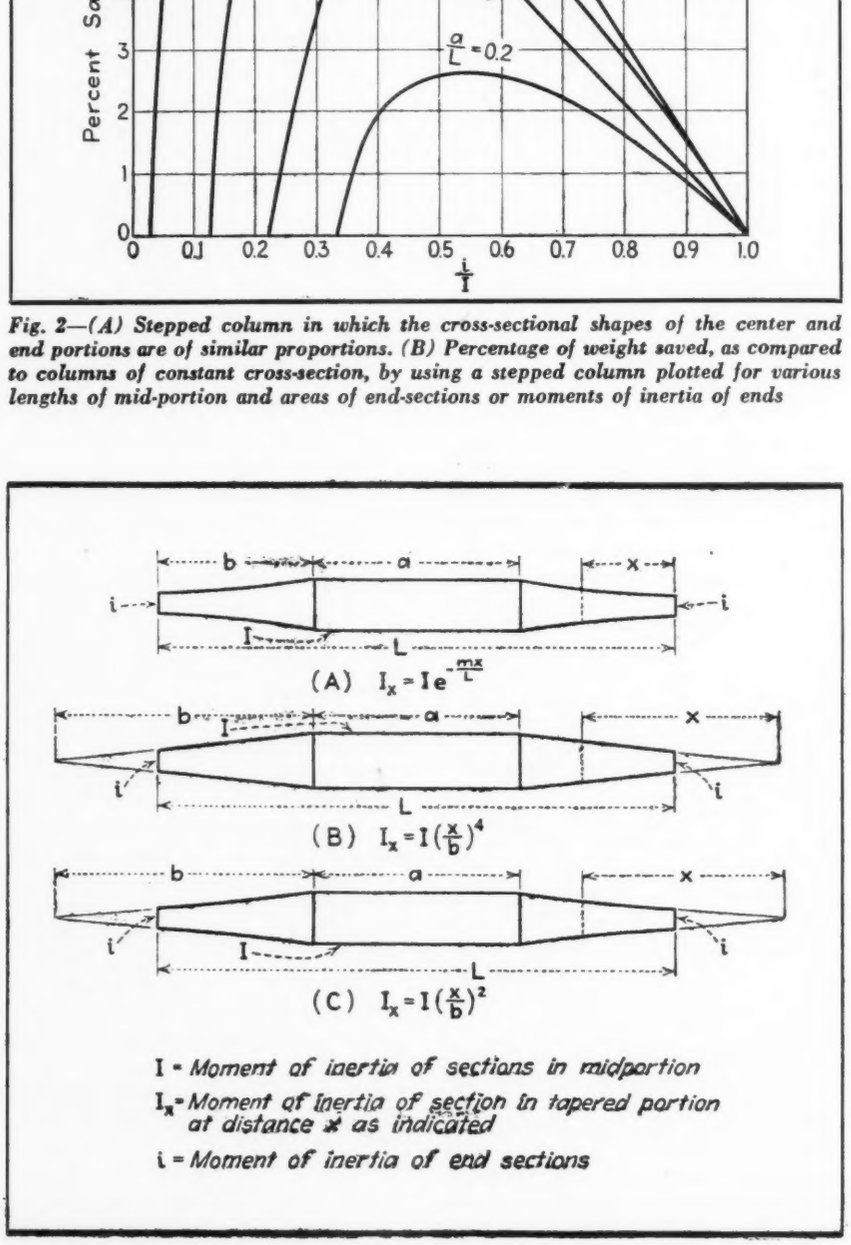


Fig. 2—(A) Stepped column in which the cross-sectional shapes of the center and end portions are of similar proportions. (B) Percentage of weight saved, as compared to columns of constant cross-section, by using a stepped column plotted for various lengths of mid-portion and areas of end-sections or moments of inertia of ends


b
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(A) $I_x = Ie^{-\frac{mx}{L}}$
(B) $I_x = I(\frac{x}{b})^4$
(C) $I_x = I(\frac{x}{b})^2$
I = Moment of inertia of sections in midportion
I_x = Moment of inertia of section in tapered portion at distance x as indicated
i = Moment of inertia of end sections

Fig. 3—Tapered circular columns in which the cross-section of the mid-portion is constant, and in which the end portions are tapered in accordance with a mathematical law. Weight saved is greater than in types having abrupt section steps

weight Z which results from using a tapered or stepped column instead of a similarly shaped, constant section column to carry the same load will also be found.

The values of Z summarized in the following paragraphs for pin ended columns do not include the required enlargements at the ends to resist the bearing loads, since the dimensions of the enlargements depend upon the physical properties of the material.

STEPPED COLUMNS may be made from pipe of different diameters riveted, welded or shrunk together, or may be constructed by attaching a stiffener to the mid-portion of a constant section column.

Values of Z for stepped columns, like that shown in Fig. 2 (*A*) having cross-sectional shapes of similar proportions, are plotted in Fig. 2 (*B*) in terms of i/I and a/L, in which i and I are the moments of inertia of the end and center sections respectively, a is the length of the mid-portion, and L is the overall length of column.

It can be noted from Fig. 2 (*B*)

Table I—Tapered Circular Columns

Type	Z_{max}	a/L	i/I
$I_x = I\,e^{-mx/L}$	11.7	0.4	0.1
$I_x = I_x\left(\frac{x}{b}\right)^4$	12.0	0.4	0.1
$I_x = I\left(\frac{x}{b}\right)^2$	12.2	0.4	0.1

(1)	(2)	(3)	(4)	(5)
$\frac{x}{L}$	I_x	y	$y_x - y$	(4)/(2)
0.00	1.000	0.000	1.000	1.000
0.05				
0.10	0.990	0.009	0.991	1.001
0.15				
0.20	0.955	0.037	0.963	1.008
0.25				
0.30	0.885	0.083	0.917	1.037
0.35				
0.40	0.800	0.149	0.851	1.063
0.45				
0.50	0.695	0.235	0.765	1.100
0.55				
0.60	0.570	0.340	0.660	1.158
0.65				
0.70	0.430	0.470	0.530	1.232
0.75				
0.80	0.270	0.621	0.379	1.402
0.85				
0.90	0.118	0.800	0.200	1.694
0.95				
1.00	0.000	1.000	0.000	0.000

that the greatest saving in weight, about 8.5 percent, occurs with a/L approximately equal to 0.8 and i/I equal to 0.2 approximately.

TAPERED CIRCULAR COLUMNS. It is to be expected that if the ends of the column are tapered according to some mathematical law, as shown in Fig. 3, greater savings in weight can be obtained than by an abrupt step in section. Dr. Dinnik has solved Equation (4) for several cases of tapering columns where I_x the moment of inertia at a section x inches from the end is a function of the maximum moment of inertia I at the mid-portion. From the equations developed by Dr. Dinnik, calculations can be made for the saving in weight for solid circular columns, or for hollow columns having a constant ratio of thickness to diameter, with tapered ends. Table I summarizes the results of such calculations for columns of the type shown in Fig. 3, and gives the maximum Z and the corresponding values of a/L and i/I for each case.

COLUMNS OF CONSTANT STRENGTH. The greatest saving in weight will occur in a column in which the stress is constant over the entire length except, of course, at the ends where the stress must necessarily be zero. The mathematical solution of Equation (4) for this condition is difficult, but an approximate method developed by Prof. A. Morley (*Engineering*, Sept. 21, 1917, p. 295) based upon difference calculus or tabular integration can be used. The basic idea of this method of calculation was outlined in an article by the author ("Difference Calculus," PRODUCT ENGINEERING, January 1942, p. 13) as applied to beam deflections.

By Morley's method the critical load of a column can be found regardless of the variation in the cross-section along the length. Sections can be selected by trial which will give a constant stress along the column, and the saving in weight Z then determined.

Since the column is symmetrical about its midpoint, only one-half of the length need be considered. This portion is equivalent to a column fixed at one end with the load applied at the free end as shown in Fig. 4. Equation (4) can then be written

$$M = E I_x \frac{d^2y}{dx^2} = P(y_a - y) \qquad (6)$$

By dividing the column into a number of equal increment lengths, for convenience each increment Δx is taken as 0.1 L, Equation (6) can be transformed to

$$\frac{E}{P L^2} y = \sum_0^1 0.1 \sum_0^1 0.1 \left(\frac{y_a - y}{I_x}\right) \qquad (7)$$

which can be integrated in table form. Table II shows the procedure.

The column is divided into equal lengths of x/L equalling 0, 0.05, 0.10, and so on, as listed in Column (1) of Table II. The moments of inertia listed in Column (2) at the even tenth points are known or assumed. The deflections at these points are assumed and listed in Column (3); the maximum deflection y_a being taken as unity or 1 inch. The integration indicated by the right side of Equation (7) is then performed in Columns (4) to (9) inclusive.

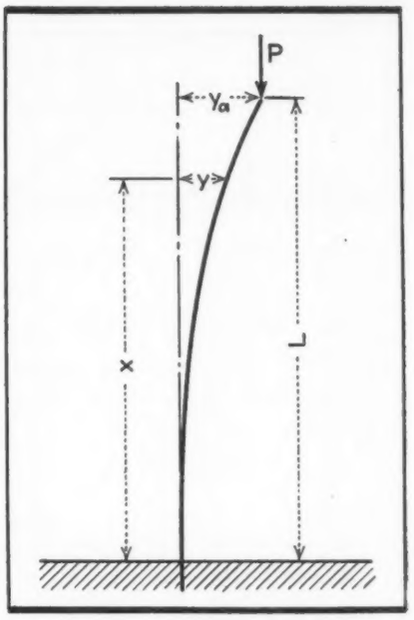
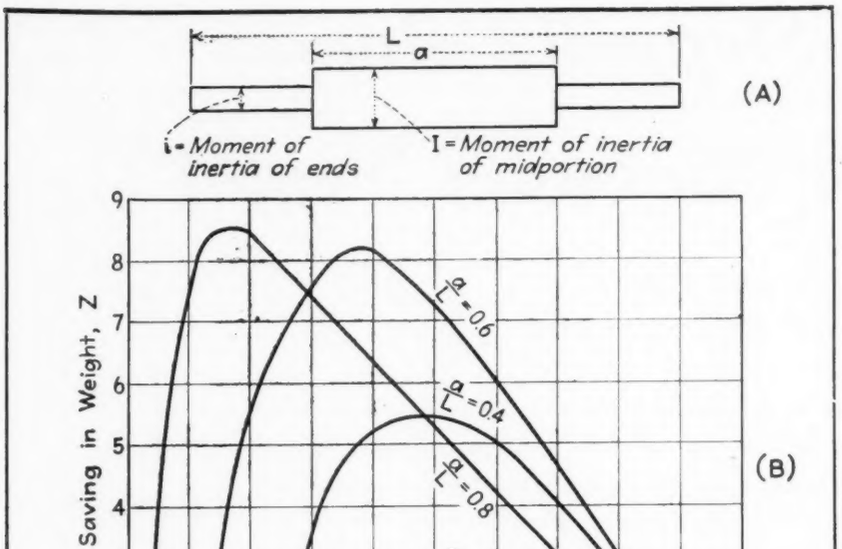


Fig. 4—Deflection curve of the center line of a column fixed at one end and with load applied at the free end

As given by Equation (7) the values of Column (9) are a function of the derived deflection curve since E/PL^2 is a constant for a given case. If the maximum value 0.5378 is made equal to y_a and the other values changed proportionally a derived deflection curve Column 10 will result. To obtain a satisfactory solution this derived curve must agree with the original assumption. If it does not,

Table II—Solution For a Column of Constant Strength

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
x/L	I_x	y	$y_a - y$	(4)/(2)	$\frac{f}{0.1}$ (5)	Σf	$0.1\,\Sigma f$	$\Sigma\, 0.1\,\Sigma f$	y'	$y_a - y'$	D_x	$\frac{(11)\times(12)}{(2)}$	S in percent	I_x	$0.1\sqrt{(15)}$
0.00	1.000	1.000	0.000	1.000		0.0000		0.0000	0.000	1.000	2.122	2.122	100.0		
					0.1000		0.0050							0.995	0.0998
0.05	1.001	0.991	0.009	0.991		0.1000		0.0050	0.009	0.991	2.120	2.122	100.0		
					0.1005		0.0150							0.972	0.0987
0.10	1.008	0.963	0.037	0.955		0.2005		0.0200	0.037	0.963	2.100	2.119	99.7		
					0.1022		0.0252							0.920	0.0960
0.15	1.037	0.917	0.083	0.884		0.3027		0.0452	0.084	0.916	2.060	2.133	100.2		
					0.1050		0.0355							0.843	0.0920
0.20	1.063	0.851	0.149	0.801		0.4077		0.0807	0.150	0.850	2.010	2.135	100.3		
					0.1082		0.0462							0.750	0.0866
0.25	1.100	0.765	0.235	0.695		0.5159		0.1269	0.236	0.764	1.938	2.126	100.1		
					0.1129		0.0572							0.633	0.0796
0.30	1.158	0.660	0.340	0.570		0.6288		0.1841	0.342	0.658	1.845	2.126	100.1		
					0.1195		0.0689							0.500	0.0707
0.35	1.232	0.530	0.470	0.430		0.7483		0.2530	0.470	0.530	1.720	2.120	99.8		
					0.1317		0.0814							0.350	0.0592
0.40	1.402	0.378	0.622	0.270		0.8800		0.3344	0.622	0.378	1.531	2.142	101.0		
					0.1518		0.0957							0.194	0.0441
0.45	1.694	0.200	0.800	0.118		1.0348		0.4301	0.800	0.200	1.245	2.108	99.4		
					0.0847		0.1077							0.059	0.0243
0.50	1.000	0.000	1.000	0.000		1.1195		0.5378	1.000	0.000	0.000	0.000	0.0		
														Total	0.7510



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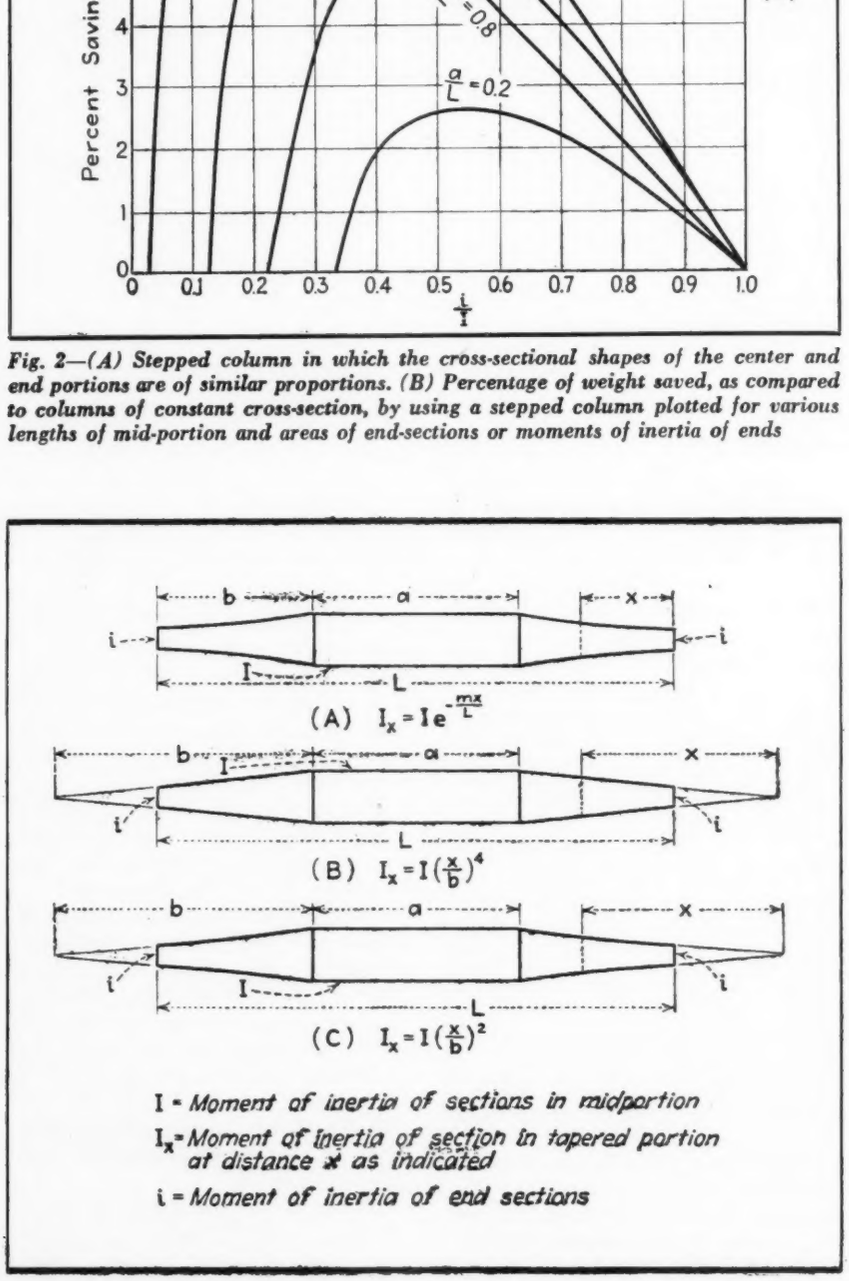
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I
L
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weight Z which results from using a tapered or stepped column instead of a similarly shaped, constant section column to carry the same load will also be found.

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Type	Z_{max}	a/L	i/I
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The column is divided into equal lengths of x/L equalling 0, 0.05, 0.10, and so on, as listed in Column (1) of Table II. The moments of inertia listed in Column (2) at the even tenth points are known or assumed. The deflections at these points are assumed and listed in Column (3); the maximum deflection y_a being taken as unity or 1 inch. The integration indicated by the right side of Equation (7) is then performed in Columns (4) to (9) inclusive.

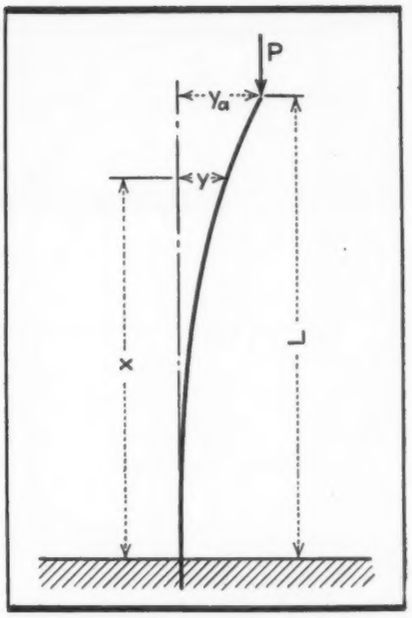

Fig. 4—Deflection curve of the center line of a column fixed at one end and with load applied at the free end

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x/L	I_x	y	$y_a - y$	(4)/(2)	$0.1 f$, (5)	Σf	$0.1 \Sigma f$	$\Sigma\, 0.1 \Sigma f$	y'	$y_a - y'$	D_x	$\frac{(11) \times (12)}{(2)}$	S in percent	I_x	$0.1\sqrt{(15)}$
0	1.000	0.000	1.000	1.000		0.0000		0.0000	0.000	1.000	2.122	2.122	100.0		
					0.1000		0.0050							0.995	0.0998
0.05	1.001	0.009	0.991	0.991		0.1000		0.0050	0.009	0.991	2.120	2.122	100.0		
					0.1005		0.0150							0.972	0.0987
0.10	1.008	0.037	0.963	0.963		0.2005		0.0200	0.037	0.963	2.100	2.119	99.7		
					0.1022		0.0252							0.920	0.0960
0.15	1.037	0.083	0.917	0.917		0.3027		0.0452	0.084	0.916	2.060	2.133	100.2		
					0.1050		0.0355							0.843	0.0920
0.20	1.063	0.149	0.851	0.851		0.4077		0.0807	0.150	0.850	2.010	2.135	100.3		
					0.1082		0.0462							0.750	0.0866
0.25	1.100	0.235	0.765	0.765		0.5159		0.1269	0.236	0.764	1.938	2.126	100.1		
					0.1129		0.0572							0.633	0.0796
0.30	1.158	0.340	0.660	0.660		0.6288		0.1841	0.342	0.658	1.845	2.126	100.1		
					0.1195		0.0689							0.500	0.0707
0.35	1.232	0.470	0.530	0.530		0.7483		0.2530	0.470	0.530	1.720	2.120	99.8		
					0.1317		0.0814							0.350	0.0592
0.40	1.402	0.622	0.378	0.379		0.8800		0.3344	0.622	0.378	1.531	2.142	101.0		
					0.1518		0.0957							0.194	0.0441
0.45	1.694	0.800	0.200	0.200		1.0348		0.4301	0.800	0.200	1.245	2.108	99.4		
					0.0847		0.1077							0.059	0.0243
0.50	0.000	1.000	0.000	0.000		1.1195		0.5378	1.000	0.000	0.000	0.000	0.0		
														Total	0.7510

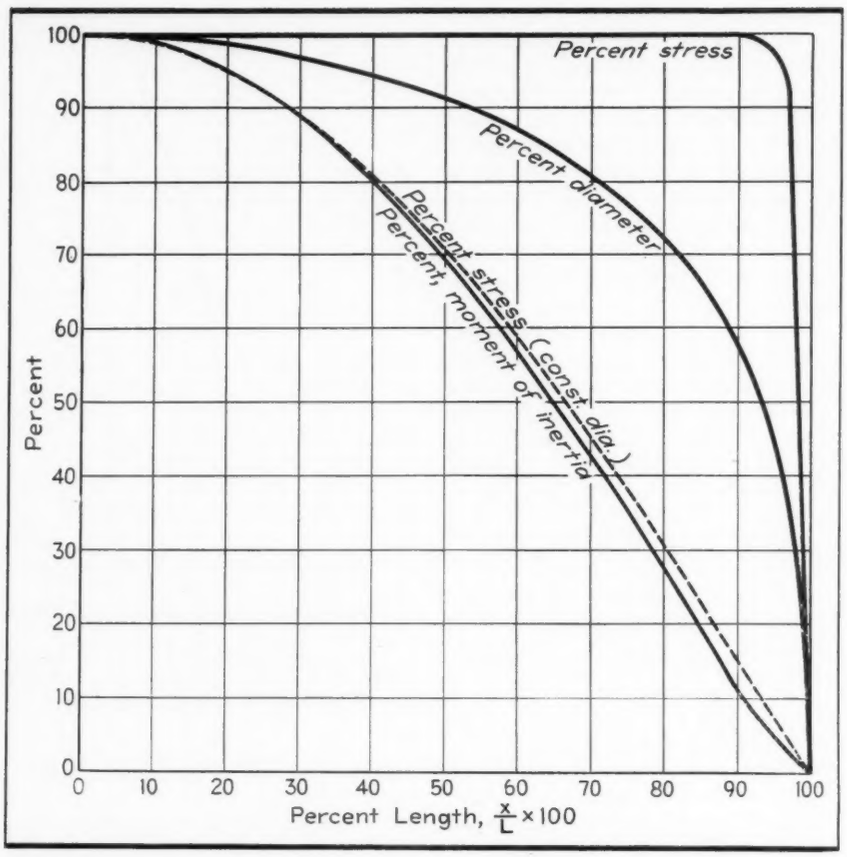


Fig. 5—Stress, moment of inertia and column diameter plotted on a percentage basis against percent length for columns of constant strength

another curve must be assumed and the process repeated until agreement is reached. Usually the derived curve is used as the assumption for the next trial. It will then be found that the process is rapidly convergent, two or three trials being usually sufficient.

After agreement has been reached, the critical load can be found from Equation (7) by using the maximum values of y and

$$\sum_0^1 0.1 \sum_0^1 0.1 \left(\frac{y_a - y}{I_x}\right)$$

that is

$$P_{cr} = \frac{E\,y_a}{L^2\left[\sum_0^1 0.1 \sum_0^1 0.1 \left(\frac{y_a - y}{I_x}\right)\right]} \quad (8)$$

If the column calculated in Table II is made of steel having E equal to 30,000,000 and is 100 in. long, the critical load is

$$P_{cr} = \frac{30{,}000{,}000 \times 1}{100^2 \times 0.5378} = 5{,}580 \text{ lb.}$$

Stress S_x at points along the column is given by the flexure formula

$$S_x = \frac{M_x c_x}{I_x} = \frac{P(y_a - y')\,c_x}{I_x}$$

If the column has a circular section of diameter D_x, c_x equals $D_x/2$ and as P is constant

$$S_x = \frac{K'(y_a - y')\,D_x}{I_x}$$

The diameters corresponding to the moments of inertia listed in Column (2) are given in Column (12). The stress functions are calculated in Column (13). Since only relative values of stress are desired and the actual maximum deflection is unknown, the stress is found in Column (14) as a percentage of that existing at the base of the column. It will be noted that the percentage stress stays within plus or minus one percent of the midpoint value for the values of I_x as assumed.

Stress, moment of inertia and column diameter are plotted in solid lines in Fig. 5 on a percentage basis against percent length. For comparison the percentage stress distribution for a constant section circular column is also plotted using a broken line. It is of interest to note that the relationship between I_x and x/L is approximated by the equation

$$I_x = I\left[1 - \frac{3}{2}\left(\frac{x}{L}\right)^2 + \frac{1}{2}\left(\frac{x}{L}\right)^3\right]$$

The required moment of inertia of a column of constant section to carry the same load as the constant strength column can be found by equating Equations (2) and (8), remembering that I equals k^2A, y_a equals 1, and C equals $\frac{1}{4}$,

$$\frac{C\pi^2 EA}{L^2/k^2} = \frac{\pi^2}{4}\frac{EI}{L^2}$$

$$= \frac{Ey_a}{L^2\left[\sum_0^1 0.1 \sum_0^1 0.1 \left(\frac{y_a - y}{I_x}\right)\right]}$$

or

$$I = \frac{4}{\pi^2\left[\sum_0^1 0.1 \sum_0^1 0.1 \left(\frac{y_a - y}{I_x}\right)\right]}$$

$$= \frac{4}{\pi^2\,(0.5378)} = 0.751 \text{ in.}^4$$

which corresponds to a diameter of 1.977 in. and a volume of 3.07 L cubic inches.

Since for a column with a circular section

$$\frac{I_x}{I} = \frac{D^4_x}{D^4}, \text{ and } \frac{A_x}{A} = \frac{D^2_x}{D^2}$$

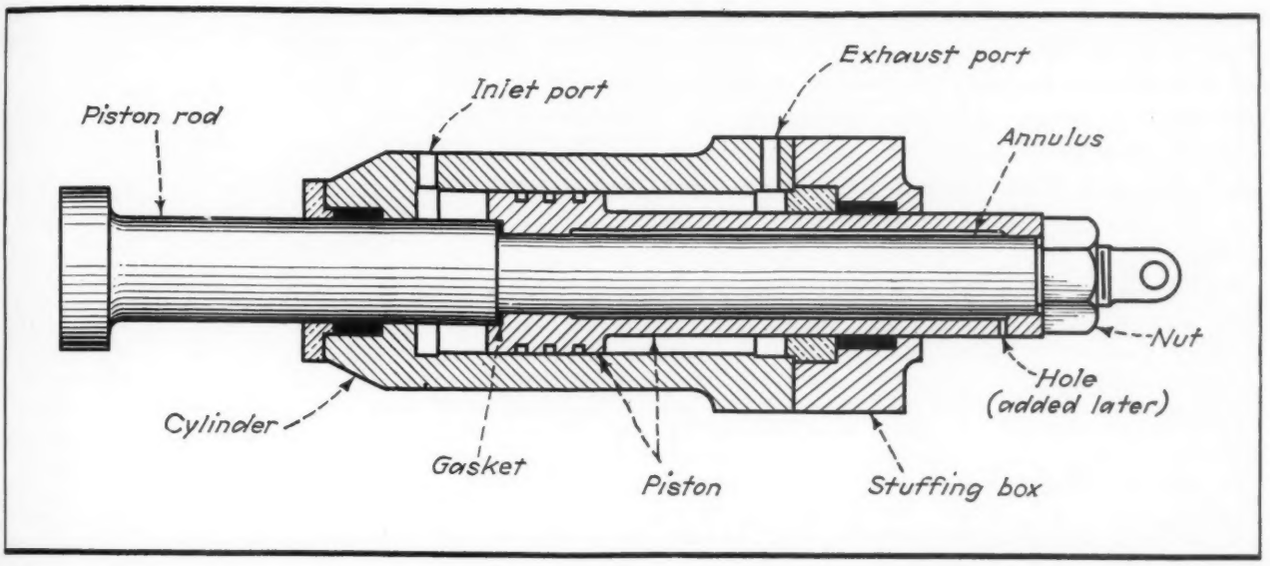
the area at any section is A_x equals $A\sqrt{I_x/I}$ or, as I equals unity, A_x equals $A\sqrt{I_x}$ The volume is approximated by $A\sum_0^1 \sqrt{I_x}\,(\Delta x/L)$ where the values of $\sqrt{I_x}$ are taken at the midpoints of the increment lengths. The values of $\sqrt{I_x}\,(\Delta x/L)$ or $0.1\ \sqrt{I_x}$, are listed in Column (16) and the summation is 0.751. The area A at the base is 3.543 sq.in. which corresponds to the moment of inertia of unity there. The approximate volume is $3.543 \times 0.751\ L$, or $2.66\ L$. Hence, the percentage saving in weight Z by using a constant strength circular column rather than a constant section circular column which would carry the same load is 13.3 percent. This is closely approached with end conditions of tapered columns solverd by Dr. Dinnik.

As the curves of Fig. 5 are plotted on a non-dimensional basis, the diameters can be used to specify a column of any length or material with a saving of weight as noted.

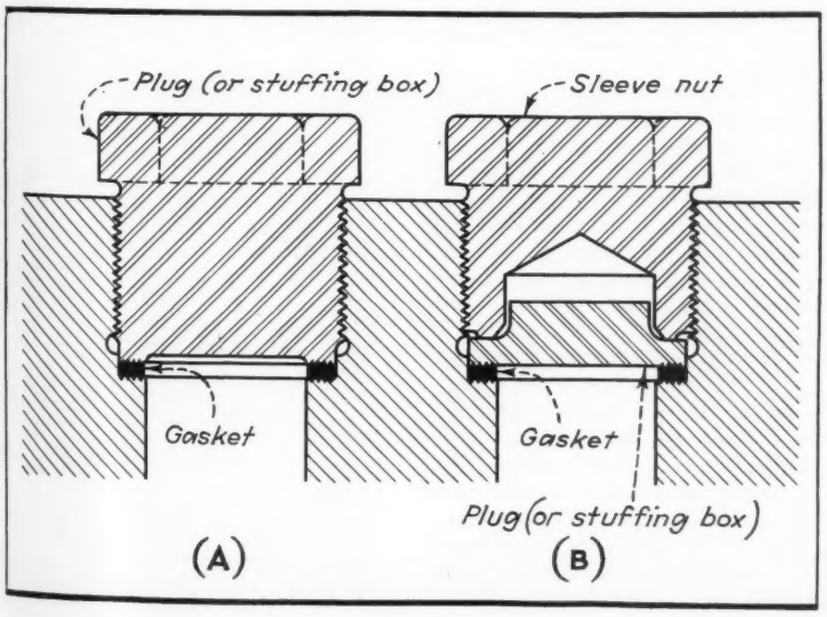
Sea Rescue Lamp

A MIDGET SEARCHLIGHT the size of a walnut yet powerful enough to project a 1,500 candlepower beam visible for 60 nautical miles has been designed by Westinghouse engineers to aid the rescue of aviators forced down at sea. The new lamp, packed with rubber life rafts, is mounted in a waterproof housing and has a single tungsten filament.

CAUSES AND CURES



Unusual construction shown for a double acting cylinder was necessitated by hydraulic area requirements and space limitations. High pressure entering the cylinder through inlet port forced the piston hard against the nut, so that fluid leaked past the gasket into annulus between the piston and piston rod. The highly loaded nut and a close fit at the small end of the piston formed an effective seal, so that pressure built up inside the annulus. First signs of trouble were extreme tightness of the piston in the stuffing box. Eventually the piston burst like a cylinder. When making a new piston the condition was corrected by drilling a radial hole through the wall of the tail end of the piston near the end of the annulus to provide a vent for leakage.



Gasket joints under plugs or stuffing boxes of the type shown at *A* may give considerable trouble caused by the shearing action of the face of the plug and the gasket when tightening. By inserting a loose piece in the end of the plug, as shown at *B*, shearing of the gasket is eliminated. With the loose piece the gasket is subjected to a simple compressive load.

PRODUCT ENGINEERING will pay a minimum of $5 for each example published in Causes and Cures. Where illustrations are necessary, include drawings, rough sketches or photographs.

Stampings Eliminate Machining In Roller Bearing Retainers

RUDOLPH R. KILIAN
Development Engineer, Rollway Bearing Company

How to obtain simultaneously both standardization and the economical manufacture of parts for roller bearing retainers has for a long time received the careful study of bearing engineers. One solution of the problem, described here, compares on the basis of quantity produced and design flexibility the advantages of machined parts and stamped parts for roller bearing retainers.

BALL BEARINGS have been so thoroughly standardized that a comparatively limited number of pressed steel retainer sizes, with die units for their production, will cover wide ranges of stock bearings. The roller-bearing industry has not been so fortunate in this respect. Except for certain standards that have been developed and adopted by individual manufacturers, there are only a small number of established S.A.E. sizes. Because of the numerous variations in bearing types and sizes, and the constant demand for small quantities of special bearings it would be difficult to design and prohibitive in cost to develop standardized one-piece steel retainers which would be comparable to ball-bearing cages.

Some small and medium sizes of roller bearings which if not directly standardized, are at least ordered and manufactured in large uniform runs, can at small cost be provided with retainers made from one-piece stampings, stamped side-rings connected by stay-rods or similar designs adapted to mass production.

The majority of precision medium to large size roller-bearings constructed with an axial guide channel, either in the periphery of the inner race or the bore of the outer race, are equipped with a type of retainer similar to that shown in Fig. 1. The retainer ring is machined from bronze or brass castings, or from tubing. The roller pockets are machined on special indexing semi-automatic machines or on drill presses using costly jigs. Burrs and sharp corners along the edges of the roller pockets are removed manually. Cover rings are turned, bored and faced. Rigid inspection for each roller pocket hole for finish, size, parallelism, radial distance and spacing is required. Retainer, rollers and cover ring are assembled to the channel race by means of rivets into a fixed unit which cannot be disassembled without destroying the rivets. This type of retainer is likely to be costly in labor and material, and heavy from a dynamic consideration.

A machined retainer has one definite advantage. It can be manufactured economically in small runs and special sizes, but the costs for tooling and production facilities, while not prohibitive, are rather high.

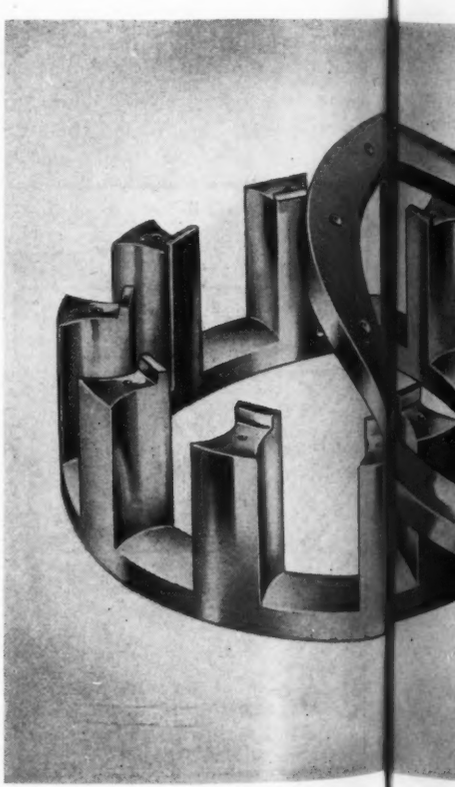
The pressed steel retainer shown in Figs. 2 and 3 has been developed as a compromise between the low cost of one-piece stampings and the production flexibility of machined bronze retainers. The new retainer is made by spot welding rectangular pocket stampings between two side rings.

The basic advantage of this design is that pocket stampings for a full range of standardized rollers can be carried in stock, which can be assembled between side rings for any desired roller spacing and size. Thus the manufacturing problem of making square, smooth and accurate roller pockets is reduced to the mass production of a stock item.

Side rings are generally stampings except for small and special lots where the die cost would be prohibitive. Pockets are deep drawn stampings, re-struck to obtain precision in size and squareness, then tumbled to obtain smooth surfaces and edges.

Holes in the side rings and pockets are used to align pin welding jigs which assure accurate spacing of the pockets between the rings and proper bearing of the rings when revolving on the inner race. Side ring rigidity and sufficient bearing capacity against the inner race is obtained by drawing a concentric flange around the bore of the ring stamping.

Each pocket has two lips bent slightly inwards. The roller cannot pass between the lips but is permitted to move enough in a radial direction to clear the bore of the side rings and also to allow the retainer with rollers in pockets to slip over the flange of the race channel. This feature facilitates assembling and disassembling. The alignment holes also serve as oil passages from the surrounding chamber of the bearing mounting into each roller pocket thus increasing the lubricating capacity of the bearing. Pocket stampings can be assembled between the side rings with lips pointing either radially outwards or inwards to suit



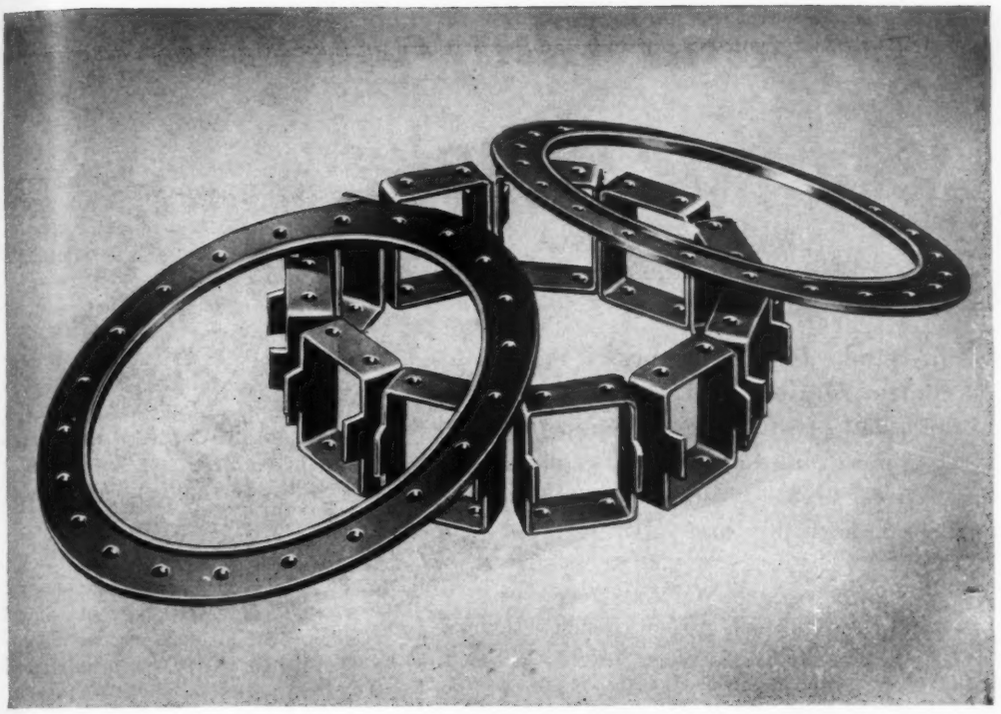


Fig. 2—Pressed steel pockets and side rings for roller bearing retainer. Pocket stampings are re-struck to obtain precision in size and squareness

Fig. 3—Complete retainer made by spot welding rectangular pocket stampings between the two side rings

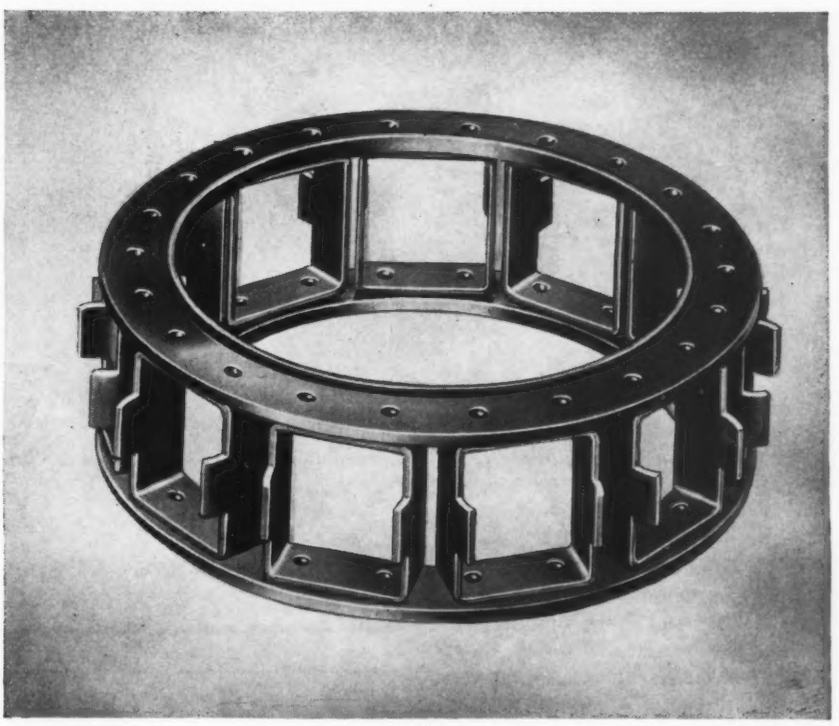
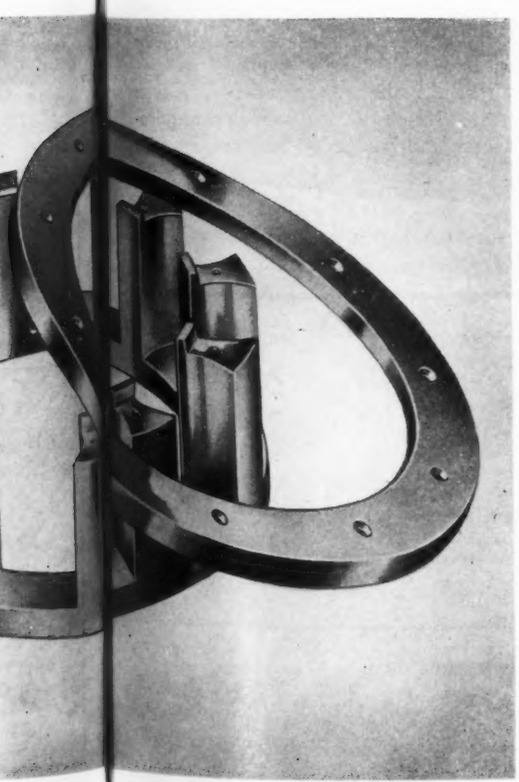


Fig. 1—Typical retainer ring and cover ring machined from bronze or brass castings. Roller pockets are machined on semi-automatic indexing machines



guide channels in either the inner or outer bearing race.

Another feature of the stamped steel design is the reduction of noise caused by the back-lash of a roller in its pocket or by a change of direction in travel. The intensity of noise varies with the back-lash or the tolerance of the pocket width against the roller diameter. Precision pocket stampings with straight sides which eliminate the crowding of the roller in a radial direction permit reducing the back-lash clearance to a minimum.

The weight of the pressed steel retainer is 40 to 55 percent less than that of the conventional machined bronze retainer. This characteristic should be of advantage in aircraft and in applications where low starting torques are essential. Also the elimination of critical metals obtained in the pressed steel retainers for channel type roller bearings is in keeping with the war effort.

Properties and Characteristics Of Ethyl Cellulose

WILLIAM KOCH
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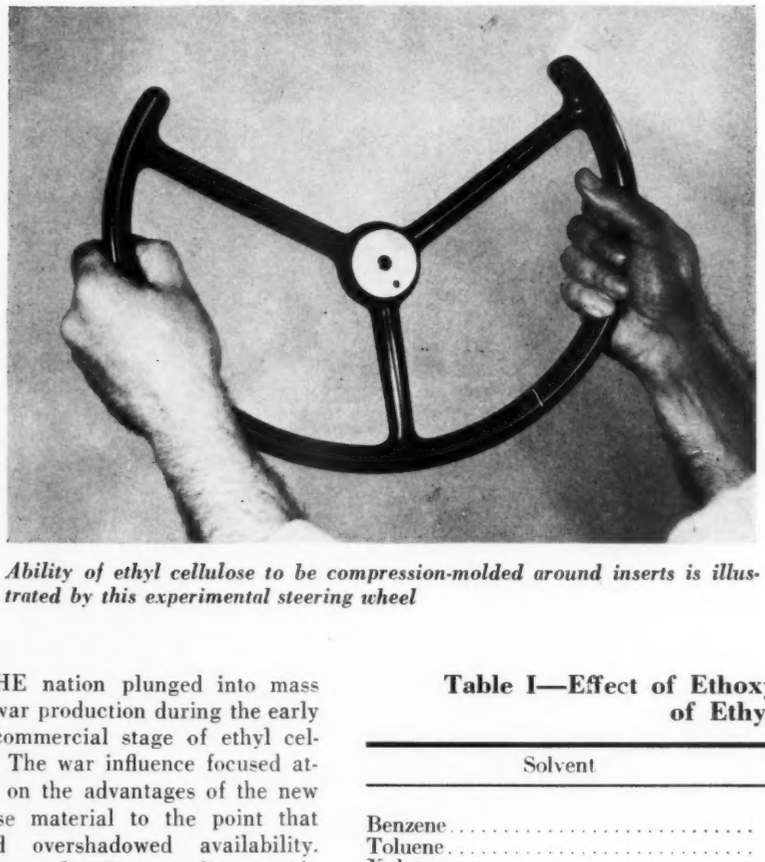
A recent development of the cellulose family of plastics, ethyl cellulose combines the strength and flexibility of the long chainlike cellulose molecules and the alkali resistance and chemical stability characteristics of ether. Toughness and flexibility are retained over a wide temperature range. Uses, beside plastic parts, include lacquers, adhesives, protective coatings, dies and jigs.



Ability of ethyl cellulose to be compression-molded around inserts is illustrated by this experimental steering wheel

THE nation plunged into mass war production during the early commercial stage of ethyl cellulose. The war influence focused attention on the advantages of the new cellulose material to the point that demand overshadowed availability. Military applications predict a wide commercial use in the postwar era.

Ethyl cellulose is derived from cellulose by treatment with strong caustic alkali and ethyl chloride to form an ether of cellulose. Its derivation from cellulose, which is composed of long chainlike molecules, gives ethyl cellulose great strength, toughness and flexibility. Its ether linkage gives it advantages over the older cellulose esters in resistance to alkalies and improved chemical stability.

Various types of ethyl cellulose are available, ranging from 43.5 percent to 50.0 percent ethoxyl content, to take advantage of the fact that certain properties vary with the degree of ethoxyl substitution. The range of types with their designation follows:

Type	Substitution Range
D ...	43.5 to 44.5 percent ethoxyl
G ...	44.5 to 45.5 percent ethoxyl
K ...	45.5 to 46.8 percent ethoxyl
N ...	46.8 to 48.5 percent ethoxyl
T ...	48.5 to 50.0 percent ethoxyl

Substitution affects solubility in organic solvents, as shown in Table I. These data indicate that there are relatively few single solvents for the lower substitution types. Solubility in all classes of organic solvents improves with increased ethoxyl content until an optimum level is reached within the range of substitution covered by the N type. Above this level solubility again becomes much more restricted, being limited in the highest levels to highly nonpolar compounds, such as the aromatic hydrocarbons. Ethyl acetate and ehtylene dichloride are solvents for all commercial substitution types.

Within the range offered, N-type ethyl cellulose meets many requirements and is usually specified because

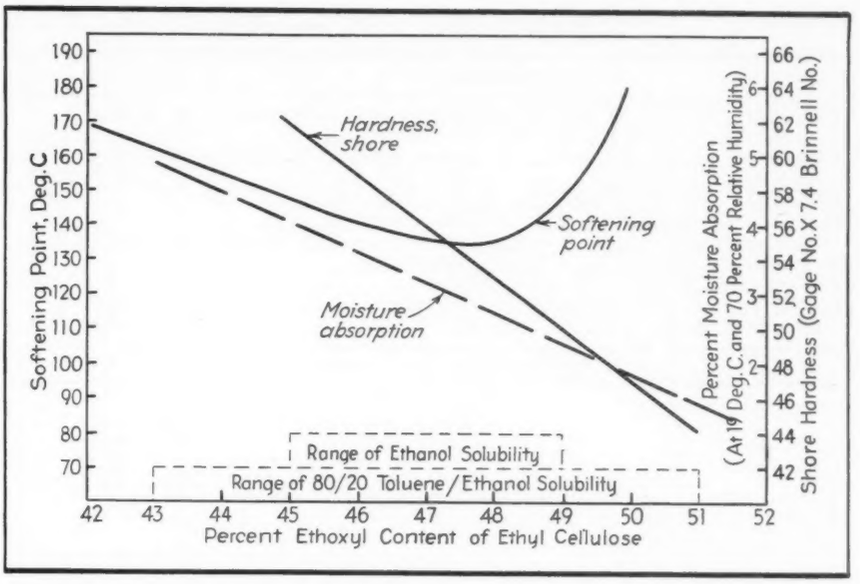
Table I—Effect of Ethoxyl Substitution on Solubility of Ethyl Cellulose

Solvent	Types				
	D	G	K	N	T
Benzene	Sw	J	J,pS	S	S
Toluene	Sw	Sw,J	J,pS	S	S
Xylene	W	Sw	Sw,J	S	S
Ethyl Acetate	S	S	S	S	S
Butyl Acetate	Sw	J,pS	J,pS	S	S
Acetone	W	J,pS	J,pS	S	J
Methanol	pS	S	S	S	W
Ethanol[1]	J,pS	S	S	S	J,pS
Butanol	Sw,J	J,pS	J,pS	S	S
Ethylene Dichloride	S	S	S	S	S
Carbon Tetrachloride	Sw	J	J	S	S
Ethyl Ether	Sw	Sw	J,pS	J,pS	S

S — soluble, free of granulations and gels.
pS — Almost soluble, but containing gels and granulation.
J — gelled.
Sw — swollen, but granules not merged into cohesive gels.
W — particles become translucent but not swollen.
[1] — 2B denatured alcohol, 95 percent strength.

it exhibits the most generally useful combination of properties. The other types are selected where special requirements must be met. For instance, D, G, and K types make harder, higher-melting compositions having better resistance to certain solvents and oils. G type, and K type to a more limited extent, are selected for injection molding because they inject without surface lamination or similar mold defects, and produce plastic parts of better resistance to heat distortion. G and K types are used in cable lacquers where oil and gasoline resistance are important. T type is useful where extreme dilution with petroleum thinners and maximum water resistance are important.

Each type is subdivided into a range of viscosity grades to meet the requirements of all types of applications. The lower viscosity grades are usually selected for surface finishes, coatings and adhesives where economy demands the maximum solids concentration. The higher viscosity grades are selected for plastics and film stock where maximum strength, flexibility and toughness are required. The data in Table II make clear that even the lowest viscosity grade has high tensile strength and a good reserve in relation to elongation and flexibility. On the other hand, tensile strength increases steadily with increased viscosity, while both elongation and flexibility appear to have reached an optimum value at a viscosity level between 100 and 200 centipoise material.



Hardness and moisture absorption decrease in a nearly straight-line function as the ethoxyl content is increased. The softening point, however, is highest at the extremes of the ethoxyl substitution range

General Properties

Specific Gravity—Ethyl cellulose is the lightest-weight cellulosic thermoplastic material available. This is important where the weight of a fabricated piece must be given consideration, because it is possible to get greater coverage or more pieces per unit weight than with most other materials.

Solubility—The solubility of ethyl cellulose in organic solvents is an important consideration in its application in surface finishes and coating compositions. The most useful mixtures consist of ethanol or butanol with aromatic hydrocarbons; tuluene substitutes such as Solvessos, Solvsols, Sovasols and Notol; esters; and ketones. The usual mixtures contain from 20 to 40 percent alcohol. These solvents can be made even more economical by dilution with petroleum thinners of appropriate boiling range, such as heptane, or VM and P naphtha.

Compatibility—Ethyl cellulose is compatible with an unusually wide variety of resins, plasticizers, oils and waxes. This offers the formulator a wide choice of modifying agents to obtain the properties desired in his application. Many modifiers are of domestic origin, inexpensive and produced in great volume. They include rosin and rosin esters; refined mineral oil; cottonseed, corn, soybean, and linseed oils; Opalwax; coal tar; coal tar pitch; stearin pitches; stearic acid; oleic acid; fatty acid esters, such as butyl stearate and butyl oleate; and gilsonite. Paraffin and high-melting microcrystalline waxes derived from petroleum, although incompatible when used alone with ethyl cellulose, can be used in appreciable quantities when blended with a mutually compatible third ingredient, such as rosin, stearic acid and coal tar. Ethyl cellulose is also compatible with many natural resins, phenolformaldehyde and rosin-modified phenolic resins, cholorinated compounds, practically all high-boiling ester plasticizers and most of the ester-type natural and synthetic waxes.

Electrical Properties—The insulation resistance of ethyl cellulose at high frequencies led to its early and continued use as a cable lacquer to protect the rubber insulation on auto-

Table II—Effect of Viscosity on Physical Properties of N-Type Ethyl Cellulose

Grade	Viscosity,* 5 percent solution, centipoises	Film,** thickness, In.	Tensile Strength, lb. per sq. in.	Elongation at Rupture, percent	Flexibility, Schopper, double folds
N-7	7.4	0.0031	7,960	7	17
N-10	9.3	0.0030	7,670	11	23
N-14	13.0	0.0030	8,100	14	42
N-22	19.7	0.0030	8,250	16	65
N-50	42.5	0.0030	8,390	14	90
N-100	93.5	0.0030	9,100	25	128
N-200	199.0	0.0030	9,240	27	218
N-300	319.7	0.0030	9,380	24	191
N-800	785.3	0.0030	9,660	23	157
N-1200	1196.5	0.0030	10,800	25	199

* Solvent was 80/20 toluene-ethanol by weight.

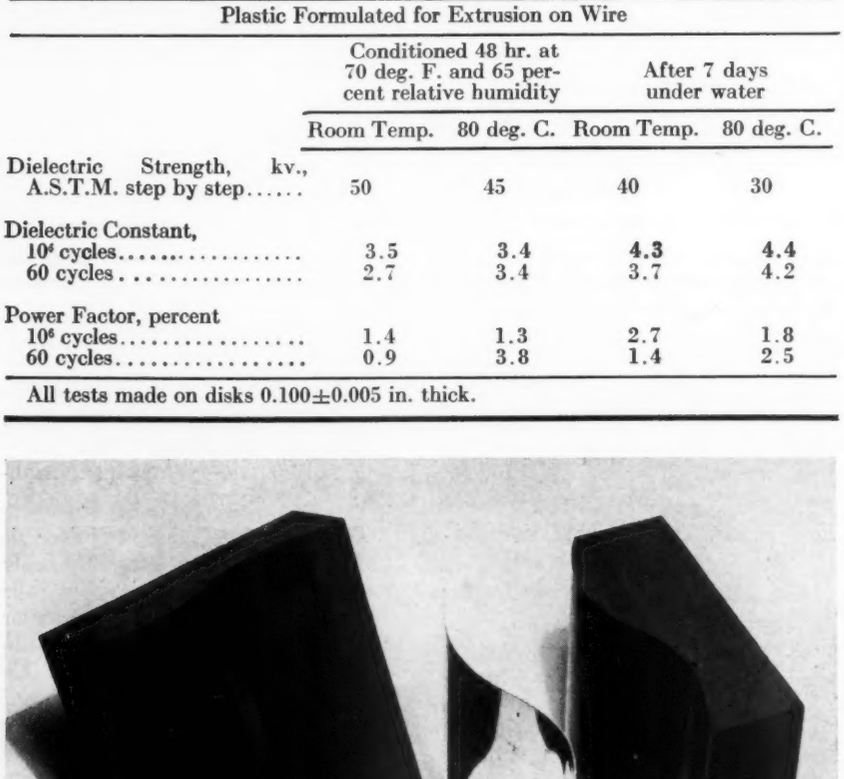
** Films for test were cast from solution in 80/20 toluene-ethanol, dried 16 hr. at 70 deg. C., conditioned 48 hr. at 70 deg. F. and 65 percent relative humidity before testing.

Table III—Electrical Properties

Unmodified Film	
Dielectric Constant, 25 deg. C., 52 percent relative humidity, 10^6 cycles, 10-mil film	3.03
Dielectric Constant, 25 deg. C., 52 percent relative humidity, 1 kilocycle, 10-mil film	3.44
Dielectric Constant, 25 deg. C., 60 cycles, 10-mil film	2.60
Dielectric Constant, 100 deg. C., 60 cycles, 10-mil film	2.90
Dielectric Strength, volts per mil., 10-mil film, A.S.T.M. step by step	1,500
Power Factor, 25 deg. C., 1 kilocycle, 10-mil film	2.5
Power Factor, 25 deg. C., 60 cycles, 10-mil film	3.0
Specific Surface Resistivity, ohms x 10^{-10}, 70 hr. at 30 deg. C. and 78.7 percent relative humidity	2,000

Plastic Formulated for Extrusion on Wire	Conditioned 48 hr. at 70 deg. F. and 65 percent relative humidity		After 7 days under water	
	Room Temp.	80 deg. C.	Room Temp.	80 deg. C.
Dielectric Strength, kv., A.S.T.M. step by step	50	45	40	30
Dielectric Constant,				
10^6 cycles	3.5	3.4	**4.3**	**4.4**
60 cycles	2.7	3.4	3.7	4.2
Power Factor, percent				
10^6 cycles	1.4	1.3	2.7	1.8
60 cycles	0.9	3.8	1.4	2.5

All tests made on disks 0.100±0.005 in. thick.



Hot-melt casting ethyl cellulose plastics are used for jigs, forming dies and tools to replace zinc and lead alloys

mobile, tank and airplane ignition cables. Its toughness, combined with unusual flexibility at very low temperatures, makes it outstanding where low temperature resistance must be met. This is particularly useful for applications where the material is extruded directly onto wire and functions as the sole insulating agent.

Flammability—Ethyl cellulose offers no fire hazard because its flammability is as low as that of cellulose. If it is held in an open flame it will burn, but fire-resistant formulations can be made by use of proper plasticizer and other flameproofing agents.

Heat Stability—Application of heat up to the melting point of ethyl cellulose has little effect on its characteristics. For this reason thermoplastic working, such as on rolls for pigment dispersion and plastic compounding, molding operations, and hot-melt application of adhesives and coatings, can be carried out without degrading the material. Ethyl cellulose is useful in formulations, such as lacquers for electric cable, where some heat resistance is required.

Water Stability—Little water is taken up by ethyl cellulose from moist air or upon immersion. What little is absorbed dries out readily, leaving the material unaffected. Dimensional stability, which is related to water absorption, is good. This property is especially valuable in plastic applications, particularly where the finished piece will be subjected to adverse exposure conditions of high humidity and temperatures up to about 71 deg. C.; no objectionable warpage occurs.

Thermoplasticity—This property is so pronounced that it is possible to process plastics completely in heated Banbury mixers or on heated two-roll mills without the aid of volatile solvents. This is of special significance at present because of the critical shortage of many of the usual compounding solvents. Thermoplasticity is an essential characteristic for forming, compounding and calendering.

Toughness—The high tensile strength and excellent flexibility characteristic of ethyl cellulose result in toughness from temperatures as low as —70 deg. C. to its softening point around 150 deg. C. This quality is carried over into compositions such as protective coatings, adhesives, film and plastics. In all these applications toughness is desirable, as, for example, in plastics for high impact resistance at low temperatures, in surface finishes for prevention of cold checking, in fabric coatings for good flexibility and cold-check resistance at low temperatures, in hot-melt compositions and in plastics for sustained strength after compounding. Ethyl cellulose in relatively small proportions incorporated into resinous or waxy mixtures exerts marked toughening action.

Typical Applications

Ethyl cellulose can be formulated into rigid and soft plastics, surface finishes, films, adhesives, calendered and protective coatings and hot-melt compositions. It may be compounded by any of the established fabricating methods.

Plastics—Injection-molded articles are usually hard, rigid compounds of high impact strength with good dimensional stability. Extrusion plas-

Table IV—Typical Ethyl Cellulose Plastics

		Characteristics When Formulated Primarily for		
		Injection Molding	Low-Temperature Resistance	Soft Plastics
Aging	Indoors	Good	Good	Good
	Outdoors	O. K. when properly formulated		
Bulking Factor		2.0 to 2.3	2.0 to 2.3	1.9 to 2.4
Color		Any desired except crystal		
Dielectric Breakdown, 10^3 volts, at 60 cycles, dry, 20 deg. C.		.....	60+	.....
in water for 7 days, 20 deg. C.		.....	44	.....
Dielectric Constant at 60 cycles, dry, 20 deg. C.		.....	3.0	.....
in water for 7 days, 20 deg. C.		.....	3.0	.....
Dielectric Constant 10^6 cycles, dry, 20 deg. C.		.....	3.5	.....
in water for 7 days, 20 deg. C.		.....	3.0	.....
Power Factor at 60 cycles, dry, 20 deg. C.		.....	3.5	.....
in water for 7 days, 20 deg. C.		.....	3.0	.....
Power Factor 10^6 cycles, dry, 20 deg. C.		.....	1.35	.....
in water for 7 days, 20 deg. C.		.....	1.95	.....
Tensile Strength, lb. per sq. in. At 170 deg. F.		960 to 1,300	900 to 1,000	Soft
At 85 to 90 deg. F.		2,000 to 4,000	1,500 to 3,000	700 to 2,400
At—70 deg. F.		5,800 to 8,600	5,500 to 6,500	2,800 to 3,300
Elongation, percent At 170 deg. F.		4 to 45	40 to 70	.....
At 85 to 90 deg. F.		2 to 20	1.60 to 15.0	31 to 169
At—70 deg. F.		0	0	.....
Charpy Impact, ft. lb. per in. of notch, A.S.T.M. D256–38 At 170 deg. F.		7.00 to 9.00	6.0 to 7.5	.....
At 70 deg. F.		1.40 to 5.00	3.0 to 5.0	.....
At—70 deg. F.		0.35 to 0.55	0.5 to 0.7	.....
Flow Temperature, deg. F., A.S.T.M. D560–40T		264 to 315	246 to 254	Low
Hardness, Rockwell M, A.S.T.M. D929–39, 70 deg. F.		32 to 60	−5 to 30	−40 to −10
Heat Distortion Point, deg. C. A.S.T.M., D48–39		49 to 61	49	.....
Machinability		Good	Fair	Poor
Refractive Index, n_D		1.47	1.47	.....
Stability to Acids, weak		Stable	Stable	Stable
strong		Not Stable	Not Stable	Not Stable
to Alkalis		Good to Excellent	Good to Excellent	Good to Excellent
Specific Gravity		1.10 to 1.14	1.05 to 1.09	1.00 to 1.06
Specific Heat, gram calories per gram per deg. C.		0.38 to 0.44	.....	.....
Compressive Strength, lb. per sq. in., 70 deg. F.		15,000 to 18,000	10,000 to 13,000	4,000 to 7,000
Flexural Strength[1], lb. per sq. in., 70 deg. F.		4,500 to 7,500	5,000 to 7,000	1,500 to 4,500
Modulus of Elasticity in Flexure[1], 70 deg. F.		170,000 to 360,000	270,000 to 300,000	80,000 to 150,000
Thermal Conductivity, cal. per cm. per cm^2 per deg. C.		4 to 6×10^{-4}	.....	.....
Thermal Expansion, Linear, in per in. per deg. C.		10 to 13×10^{-5}	.....	.....
Water Absorption percent gain, 24 hr. immersion at 70 deg. F.		1.00 to 1.30	1.2 to 1.4	.....
A.S.T.M. D570–40T, percent plasticizer leached out		0.04 to 0.10	0.1 to 0.2	.....

Specific volume of a typical ethyl cellulose formulation in solution approximates 24 cu. in. per lb.

[1] Data obtained with Tour-Marshall Stiffness Tester.

tics are usually characterized by great toughness and flexibility at very low temperatures and are usually formulated to have good electrical properties and dimensional stability. Plastics for calendering are usually very flexible and supple, yet wear resistant and tough.

Surface Finishes—There are almost as many different types of finish as there are surfaces to be coated. The data in Table V, illustrative of a typical ethyl cellulose lacquer for rigid surfaces, can be altered by varying the type and proportion of modifying agents.

Hot-Melt Casting Plastic—A typical recent development has been the use of ethyl cellulose hot-melt casting plastics as jigs, forming dies and tools for the aircraft industry to replace zinc and lead alloys commonly employed for die casting. The heat stability of ethyl cellulose makes it possible to melt and reuse such a casting plastic a number of times with no apparent deterioration in strength or toughness. Many other possibilities exist for similar hot-melt applications of ethyl cellulose.

No special or unusual precautions are necessary for handling and compounding ethyl cellulose. Its future large-scale use is assured because it has been investigated by numerous manufacturers.

Table V—Data from a Typical Ethyl Cellulose Lacquer as Applied on Different Surfaces

Adhesion to	
Steel	Good
Copper	Good
Aluminum	Fair
Tin Plate	Good
Zinc	Fair
Cellophane, untreated	Good
Wood, filled	Poor
Plaster	Good
Glass	Poor
Sensitivity to	
Water after 24 hr.	Temporary blush
5 percent NaCl solution after 24 hr.	Slight temporary blush
5 percent HCl solution after 24 hr.	Slight temporary blush
5 percent NaOH solution after 24 hr.	Unaffected
Sward Hardness	50
Flexibility	Very flexible
Gloss	Good
Sanding	Fair
Temperature Change, cycles	50+
Weathering Resistance	Very good

TYPES OF VALVES USED IN

Valves are the nerve center of hydraulic circuits. In machine tools, they provide reversal of motion, dwell and throttling action, sequence control, and relief of oil pressure. Some of the common forms of these valves are illustrated. Data and illustrations supplied from Socony-Vacuum Oil Company publication "Hydraulic Systems."

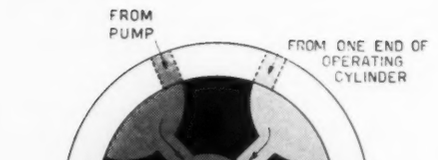


Fig. 1—Schematic diagram of rotary reversing valve. Oilways in an oscillating cylindrical plug register with ports which connect both the main oil line from the pump and the discharge line to the reservoir with either end of the operating cylinder. When oil is directed from the pump to one end of the operating cylinder, oil in the other end of the cylinder is discharged through the reversing valve to the reservoir. One position of the reversing valve shown.

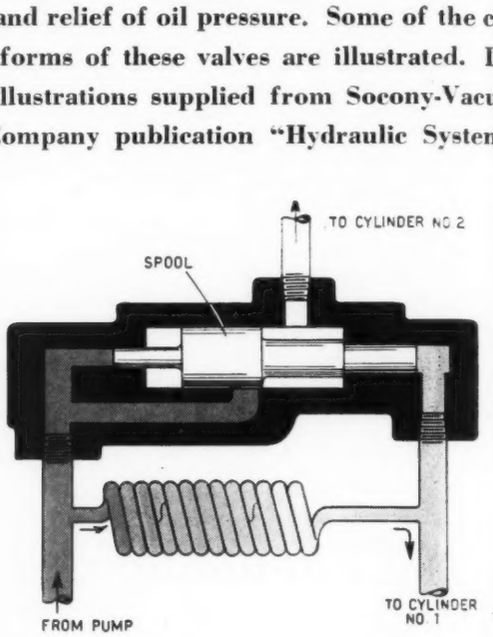


Fig. 2—Sequence control valve. Some machines are designed so that one series of motions must be completed before another series can start. This type valve prevents the flow of oil to No. 2 operating cylinder until the motion in No. 1 cylinder has been completed. Both ends of the freely floating spool are under oil pressure. The end exposed to pump pressure is smaller than the end exposed to pressure from No. 1 cylinder. From the pump, oil flows through a coil of tubing which slightly restricts the oil flow.

Pressure in No. 1 cylinder and on No. 1 end of the valve spool is less than the pump pressure, and this difference on the ends of the valve shifts the spool towards the low pressure side. Flow of oil to No. 2 cylinder is prevented. When motion in No. 1 cylinder is completed, oil no longer flows through the coil. Pressure on both sides of the valve is equalized. Full pump pressure now acts on the large end of the spool, and the spool shifts to admit oil to No. 2 cylinder.

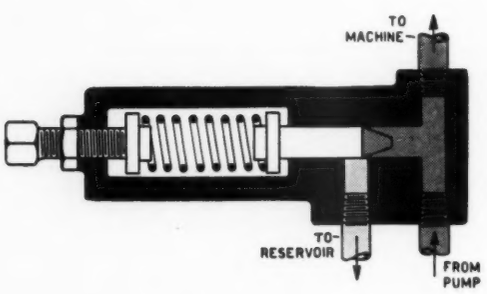
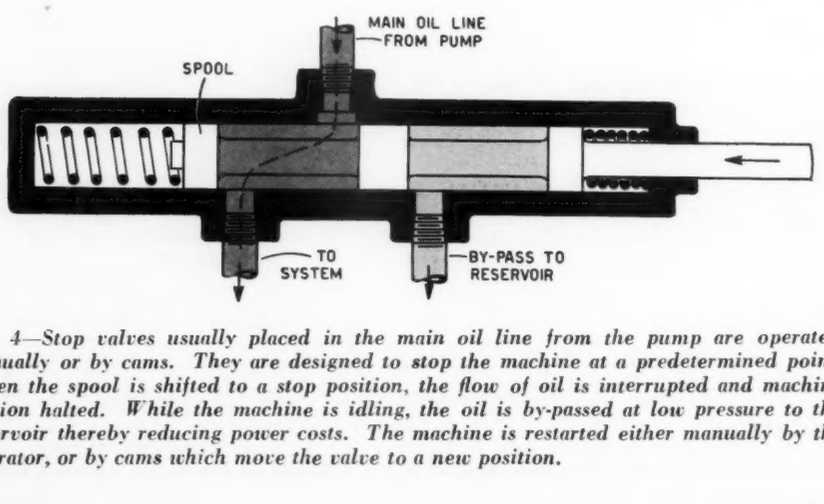


Fig. 3—Spring-loaded relief valve. This valve is placed in the pump discharge line to permit oil to escape from the line to the reservoir when the amount of oil delivered by a constant-discharge pump is more than is needed. High pressure overcomes the compression of the spring, lifts the valve from its seat, and by-passes the oil until the pressure drops below the compression adjustment of the spring.



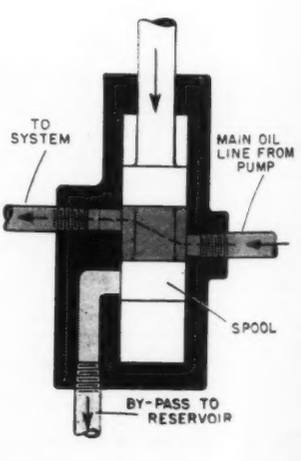


Fig. 4—Stop valves usually placed in the main oil line from the pump are operated manually or by cams. They are designed to stop the machine at a predetermined point. When the spool is shifted to a stop position, the flow of oil is interrupted and machine motion halted. While the machine is idling, the oil is by-passed at low pressure to the reservoir thereby reducing power costs. The machine is restarted either manually by the operator, or by cams which move the valve to a new position.

HYDRAULIC TRANSMISSIONS

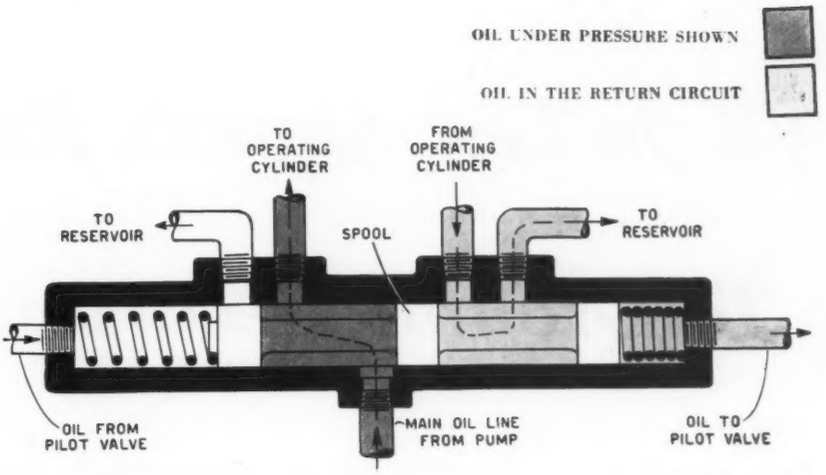


Fig. 5—Reversing valve. This valve directs oil flow in and out of either end of an operating cylinder. A separate pilot valve, Fig. 6, controls the oil pressure. The reversing-valve spool maintains a central position and floats between two springs. Pilot valve action moves the spool. When the spool is at one end of the valve, oil under pressure flows from the pump through the valve into one end of the operating cylinder, and at the same time, oil in the other end of the operating cylinder is discharged into the reservoir.

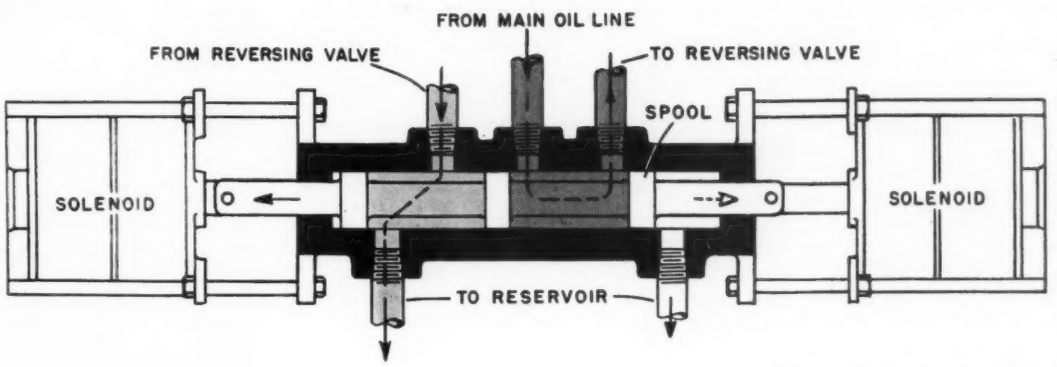
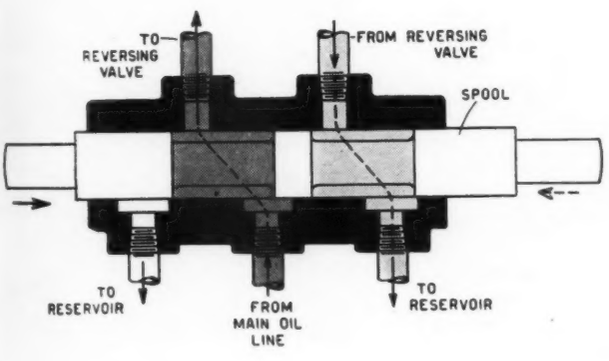
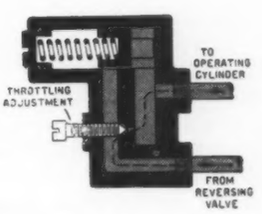
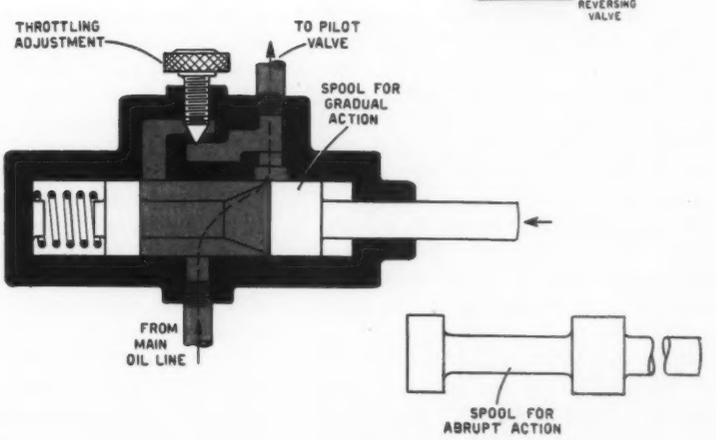


Fig. 6—Pilot valve. (above and left) Spools of these valves are thrown by cams or dogs, or may be moved magnetically by solenoids. Oil pressure from the pump is directed alternately to both ends by means of a reversing valve, Fig. 5.







Figs. 7 and 8—Dwell and throttling valves. These spring-loaded valves are actuated by cams or oil pressure. Cam action moves the spool and shuts off this free oil delivery, permitting only a restricted oil flow through throttling adjustment. In the pilot valve line, this valve delays action of the reversing valve and permits a period of dwell at the end of the stroke of the operating piston. The change from free to restricted flow may be abrupt or gradual, depending upon the spool employed. In pressure actuated valves, Fig. 8, the valve is normally held closed by the spring. Delivery of oil is restricted by a throttling adjustment as long as the valve is closed. When flow is reversed, oil pressure lifts the valve and permits free delivery of the oil.

Illustrations © Socony-Vacuum Oil Company

Flight Test Signals Relayed To Ground Recording Devices

Radio recording is employed in flashing simultaneous readings from a plane in flight to ground receiving and charting apparatus. Part I described the use of this testing device developed by the Consolidated-Vultee Aircraft Corporation. This final article deals with calibration of instruments and the conversion of transmitted signals into actual readings. This plan of sending readings while an engine is in motion can be used in testing other machines

ACCURATE, permanent recordings of instrument readings and other factors essential for comprehensive test studies of new airplanes in flight are provided in a testing device which has established its worth in experimental operations.

Developed by the Consolidated-Vultee Aircraft Corporation, the apparatus is capable of transmitting 100 different instrument readings per second to the ground receiving sets. To transmit the test information accurately, the instruments used are calibrated to conform with electrical impulses.

Equipment required for transmitting the readings was described in the July issue of PRODUCT ENGINEERING.

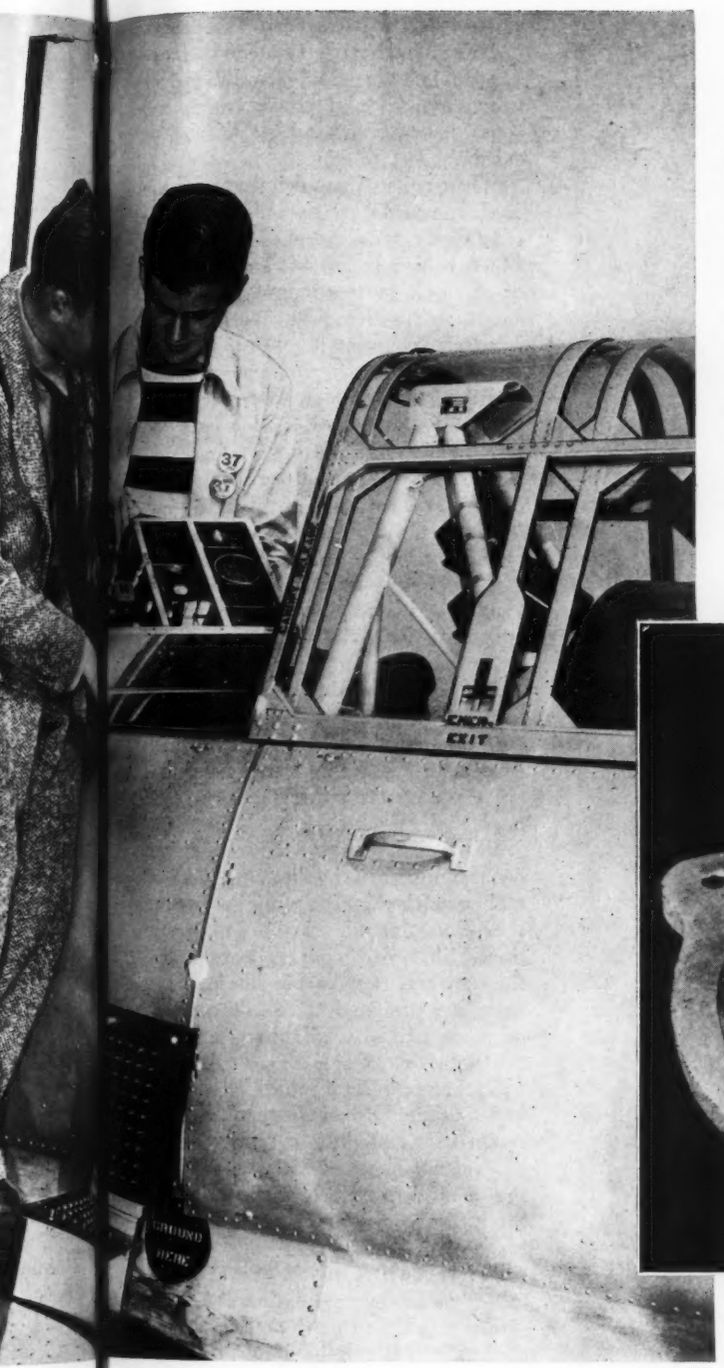
In present operations, a change of 5,000 cycles per sec. for the total range of each instrument has been arbitrarily chosen as full scale. Each pickup is designed to cause a 5,000 cycles per sec. change in the converter unit when the pickup is subjected to the maximum change in stimulus which it is required to measure. Graphic recorders are used as frequency meters, responding full scale to 5,000 cycles per sec. change.

A strain gage, having a range of 50,000 lb. per sq. in., and subjected to 10,000 lb. per sq. in. load, will produce a change of 1,000 cycles per sec. in the converter unit and will be plotted at 1/5 full deflection on its chart. An air speed pickup designed for a 500 m.p.h. range will, when the ship is flying at 100 m.p.h., cause a frequency change of 1,000 cycles per sec. in the converter, and will be charted at 1/5 full deflection on a similar chart calibrated at 500 m.p.h. full range.

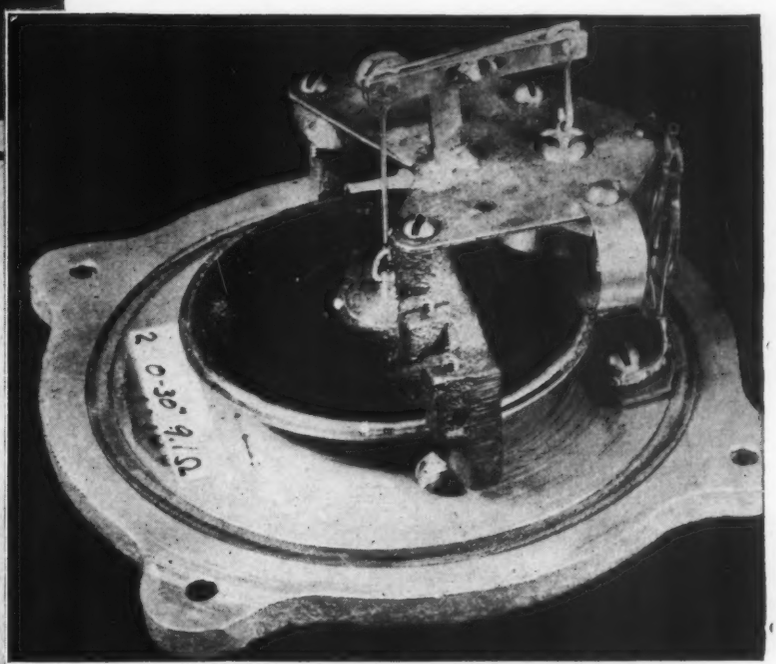
As an additional accuracy control on the system, two dummy gages are included among the active gages on the plane. These are designed to produce 1,000 and 5,000 cycles per sec., i.e. a 4,000 cycles per sec. spread between them in the converter unit. These gages furnish a check and a control on the system. If any variation occurs in the equipment in the airplane due to changes of power supply, temperature, or weak tubes, the 4000 cycles per sec. spread when charted will indicate the change. This change can be corrected immediately by an adjustment on the analyzer. The charted output of two dummy check gages in the airplane serves to indicate and correct frequency drift and frequency spread. In case of a change in frequency spread between the two dummy check gages, there is available on the analyzer another adjustment to hold its calibration to the correct spread as noted by plotted output of the check gages.

The instrument frequency can be projected, when recorded on film, and the cycles per sec. determined to an average accuracy of 1 part in 250. If a large number of such determinations are required, the work can be facilitated by projecting the instrument frequencies on a revolving drum calibrated in cycles per sec. This slow method is used only for check calibrations or where extreme accuracy is desired. Normally, automatic analysis is used for all readings wherever an overall accuracy of 1 percent is satisfactory.

Strain gages used have a resistance



Special instruments and gages connect with this unit of the Vultee radio flight test recorder. Under all conditions of operation, electrical signals are dispatched to ground receivers with speed approaching that of light. Compact and weighing less than 70 lb., the unit is designed for use when testing small or large planes in flight.



Construction of typical pressure pickup. A leverage fulcrum gives full armature movement for diaphragm deflection at the required range

of 88 ohms and vary 2 ohms over a range from −60,000 to +60,000 lb. per sq. in. stress in 24 ST aluminum alloy. When it is desirable to measure small loads under special conditions, the converter unit can be made to swing through its entire range by increasing the gain on the bridge amplifier so that strains can then be read over a total range of approximately 3,000 pounds.

As other types of pickups are more sensitive than required, shunts or multipliers are normally used. In the case of temperature measurements, (Fig. 1, July, PRODUCT ENGINEERING) specially designed resistance type thermometers may serve as the arms of the a.c. bridge for temperature measurement. Measuring units are made to approximate specification ranges and then, by the use of proper multiplier resistances in series with the unit, the ranges are adjusted.

Temperature units are single layer windings approximately one inch long of No. 36 copper wire on a thin core of copper tubing. The resistance versus temperature characteristic of this unit is a straight line.

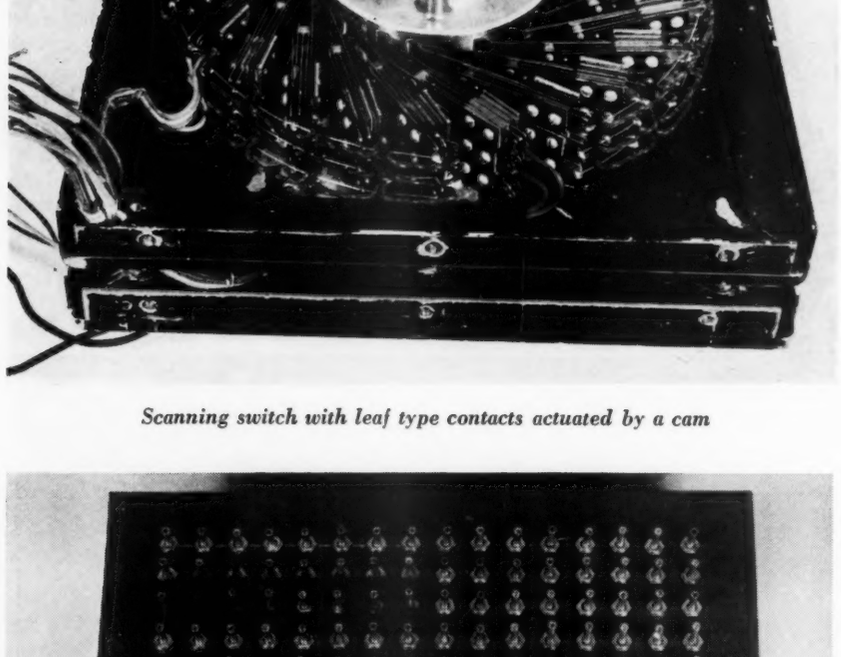
A standard temperature unit for 150 deg. C. range contains approximately four ohms of No. 36 wire in series with 100 ohms of zero temperature coefficient resistance in its arm of the bridge. The amount of resistance used in the other arm of the bridge determines the zero of the range, that is, if 104 ohms are used with all values taken at room temperature of 20 deg. C., the bridge will balance at 20 deg. C., and will cause a frequency output from the converter of 500 cycles per sec.

When the temperature at the pickup is increased to 170 deg. C. the converter frequency will become 5,500 cycles per sec. If, however, it is desired to measures from −70 deg. C. to +80 deg. C., the same unit can be used with 100 ohms in series with the active unit and 100 ohms plus the resistance of the unit at −70 deg. C. This would cause the bridge to balance at −70 deg. C. and would provide a frequency of 500 cycles per sec. at −70 deg. C., and a frequency of 5,500 cycles per sec. at +80 deg. C.

In actual operation, units are set to measure the desired ranges, and individual chart calibration strips are prepared for each unit. These strips are attached to the final charts from the analyzer, thereby using the entire chart width for all pickups regardless of their respective ranges. Each unit and the graphic recorder cover the same frequency spread.

The same conditions of flexibility

Scanning switch with leaf type contacts actuated by a cam



Plug and jack terminal board

exist in the pressure units. To measure pressures, standard diaphragm gages are used. Movement of the diaphragm causes a small armature to move lineally between two coils which form two arms of a reactance bridge. A given diaphragm using the same reactance coils can be used to record full scale charts on ranges of 0 to 20 in., 0 to 30 in., 0 to 60 in. water, or from 0 to 10 in. when using mercury.

The maximum unbalanced condition of the reactance unit when measuring pressure is shunted with sufficient resistance to cause the bridge unbalance to activate the converter to 5,500 cycles per sec. The standard reactance unit, used in most of the Vultee Radio Recorder pickup units consists of two coils each ¾ in. O.D. x $\frac{7}{16}$ in. long having equal inductance (approximately 1.5 millihenries) wound on a ¼-in. copper tube, and separated and covered by $\frac{7}{16}$ in. iron casing.

When coils of equal inductance are used, the armature extends from center to center of the coils in the balanced bridge condition, and moves $\frac{3}{32}$ of an inch to maximum unbalanced condition. In this latter position, the armature completely closes one coil and opens the other. Some pressure instruments have an excessive diaphragm movement, in which case the zero bridge balance condition is obtained by the armature completely closing one coil and opening the second coil. In this case, the maximum unbalanced condition is obtained by moving the armature a distance equal to the width of one coil instead of only half the width as in the case of balanced coils.

The armature in all cases is an iron sleeve mounted on an aluminum core and is of such small mass with respect to the diaphragm forces, that vibration effects on the unit may be neglected.

Position indicator calibration can be accomplished by both mechanical and electrical means. Wire wound potentiometers of suitable values are used with multiplying resistors to give the correct range. Mechanical systems are designed to use 50 percent or more of the available rotation of the potentiometers.

Tachometers are multiple alternators designed to convert the desired range of r.p.m. into a related range of cycles per sec. which falls within the established frequency swing of the radio recorder. The output of the tachometer unit is fed through the scanning switch to the radio transmitter as audio modulation.

The number of poles on the tachometer unit is determined by the range of r.p.m. to be scanned. Let us assume that records of engine speeds between 500 and 4,000 r.p.m. are desired. Since the tachometer shaft rotates at ½ engine speed, a 120-pole generator would, at an engine speed of 500 r.p.m., produce 500 cycles per sec. and at 4,000 engine r.p.m. would produce 4,000 cycles per sec.

This generated signal can then be recorded and analyzed by the same methods used to record and analyze the signals from the converter unit. The frequency generators used with the radio recorder consist of a steel gear the teeth of which pass the pole of a permanent magnet. In this ex-

ample, a 120-tooth gear would be used.

Since all pickups are set to a "common denominator," calibration of the converter unit is accomplished by setting the gain of the bridge amplifier to produce the desired frequency swing. For ease of calibration, this "common denominator" has been fixed as the amount of change on the output of an equal arm bridge or 100 ohms in each arm when one of the arms is changed 2 ohms. The normal frequency swing of the converter is set at 5,000 cycles per sec., permitting the operation of the automatic analyzer at any points between 500 and 6,500 cycles per sec.

This flexibility of frequency shift in the analyzer affords primarily a safety factor to be used in case the basic zero of the converter drifts from its set frequency. Should a drift of the basic frequency be encountered, there is available on the analyzer a correcting adjustment which permits the charts to be plotted on the basis of 5,000 cycles per sec. change equal to full scale, regardless of whether the 5,000 cycles per sec. is between 500 and 5,500, or between 1,500 and 6,500.

All pickups are laboratory calibrated in relation to fixed gages. Any changes occurring in other parts of the equipment are corrected at the analyzer so that the fixed dummy gages appear on the charts in their correct ratio, thereby assuring the correct ratio for all other pickups. In other words, 0 to 5,000 cycles per sec. swing equals full chart scale equals any desired stimulus range.

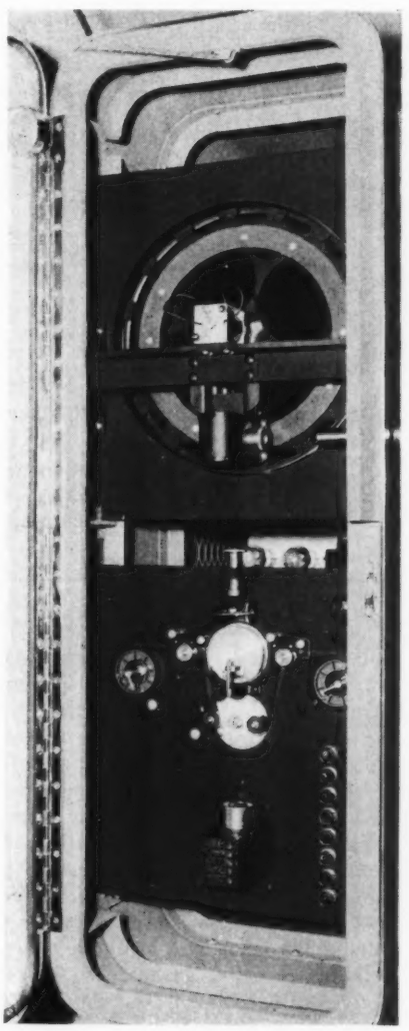
Scanning Switch

Various types of wiping contacts for the scanning switch were investigated and found to be unsatisfactory at high speeds because of vibration. The present type switch consists of leaf type contacts actuated by a cam. One arm and the amplifier input of each bridge pass through the switch, while the opposite arm is connected directly to a converter connection common to all pickups. The arms of the bridge are completed before the amplifier input contact is made, thereby preventing overloading in the amplifier while the bridge is open on one arm.

The tangential arrangement of the switches with respect to the cam allows the actuating arms of the leaf switches to ride on the small circumference of the cam, thus suppressing vibration and bouncing. Speed changes in scanning are accomplished by electrical control and by changeable gears mounted on the outside of the switch box. The present switch contains 72-contact point sets mounted in three banks of 24 contacts each. Any one of the banks may be scanned continuously or two or three banks may be scanned in succession. This is accomplished by associated gear trains and electric plug-in-jacks.

In addition to scanning the pickups, by means of additional gear trains and contact points, the switch stops the signal from the converter during the intervals between each instrument reading. This unmodulated section serves as a division between instruments during analysis of film recordings. The black part of the unmodulated track is used as a framing mark in the analyzer and operates an automatic photo cell framing device.

Special contacts are used to open the signal line from the converter during the time a tachometer signal is coming through. All contact points of the switch are wired to one side of a plug and jack terminal board on which any desired sequence of instrument readings may be arranged.



Automatic optical film analyzer

Optical Analyzer

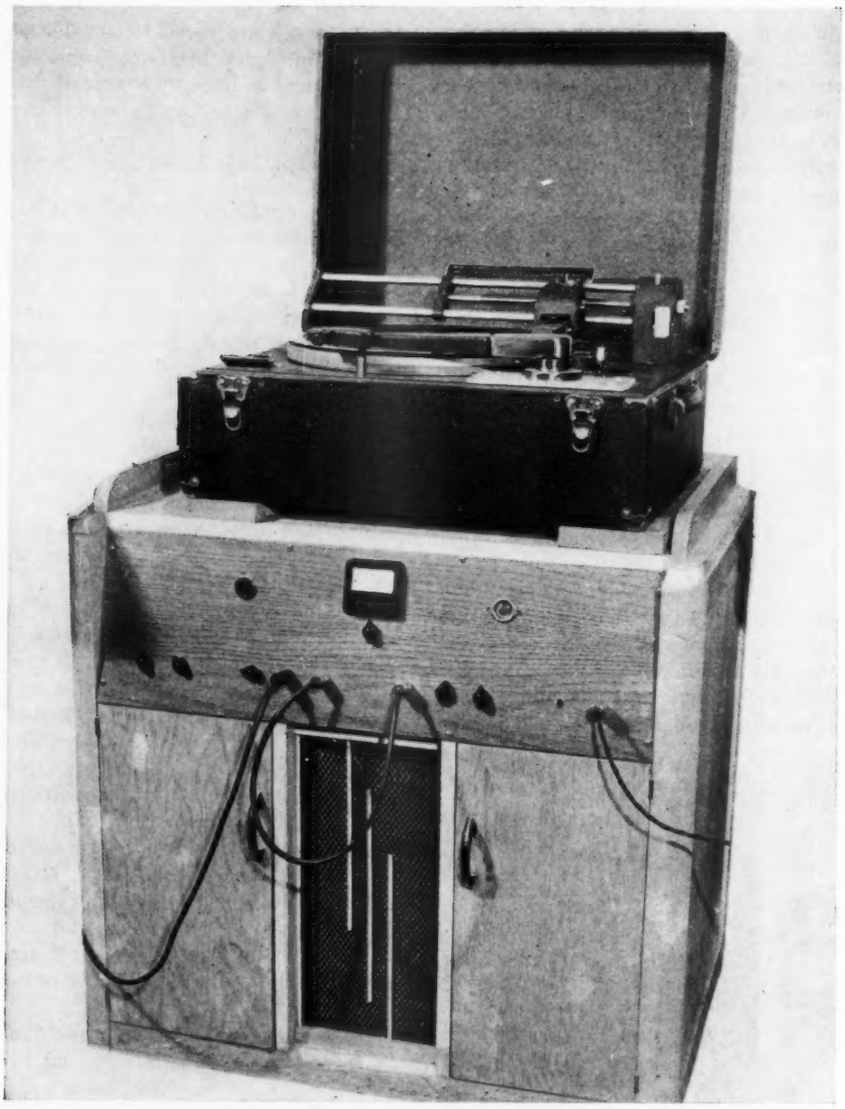
Conversion from changes of stimuli to changes of frequency in the converter unit in the airplane can be considered instantaneous because the entire process is electronic. The speed of decoding these frequencies and plotting them on charts is controlled by the time element imposed by the mechanical devices used. While amplitudes in flight can be taken as fast as 100 per sec., the automatic analysis and plotting on separate charts of the recording made at this speed require three or more seconds per instrument.

The optical analyzer consists of a means for projecting successively each instrument frequency as recorded, through a scanning mat and to a photo cell. The term "instrument frequency" refers to the one group of striations. The scanning mat, mounted on a revolving drum, consists of a transparent film on which is recorded a continuous sound track which varies from 500 to 6,500 cycles per sec. As the scanning image passes across the stationary image of the instrument frequency, a low amplitude modulation of the light beam is produced.

At the moment the scanning frequency matches the projected instrument frequency, the two images are superimposed and thus pass the maximum amount of light. They next become adjacent to each other and shut off all of the light. This alternating sequence produces a surge of high amplitude light modulation which, through the phototube and associated circuits, operates the graphic charting equipment. The sequence of charting operations, automatically performed by the analyzer, follows:

1. Without contact, the recording pen moves across the chart in relation to the rotation of the scanning mat.
2. Matching surge causes the pen to strike the paper.
3. Pen returns to zero.
4. Endless chart belt moves ahead to the chart for the next instrument.
5. Film moves ahead to the next instrument frequency.
6. Cycle repeats when steps 4 and 5 are complete. To prevent premature operation of any part of the analyzer, interlocking relays are provided.

If 72 instruments are scanned in



Disk recorder and electronic discriminator

the airplane, an endless belt of 72 charts is used in the pen recorder. After the decoding has been completed, the charts are cut apart to give a separate chart for each instrument, with all charts covering the same flight time element.

When the radio recorder is operated at speeds not exceeding the mechanical lag of the paper recording equipment used, direct paper charts of the instrument readings can be made at the ground station as they are scanned in the airplane. The Esterline Angus Graphic Recorder used with the analyzer can be used for plotting the instrument readings, provided they are scanned at a rate not to exceed one reading per second, which is the time lag of the recording pen.

The decoding in this case is accomplished by means of electronic circuits. The transmitted instrument frequencies are fed from the radio receiver into a limiter circuit which keeps the amplitude of the signal constant during input variations of from 15 to 25 volts. The signal is then fed to a discriminator circuit which produces a direct current varying in proportion to instrument frequency. This direct circuit is used to operate the meter element of the graphic pen.

In addition to the electronic analysis, a disc record is cut as the signals are received. The recording serves as a permanent record of the flight and a safety record in case of failure of the graphic instruments. A standard commercial disk recorder is used with changes made to insure freedom from recording noise and speed variations. The records are cut at 33⅓ r.p.m. with 130-140 lines per inch.

The disk recorder is mounted on a cabinet containing the limiter circuit, the discriminator, amplifier, speaker, amplitude indicator, and amplitude control. Jacks are provided for input and output to various recorders. A microphone is used to record identification and other data desired on the record to compliment the instrument signals. The records can be played back and re-recorded on film for later analysis.

Synthetic Rubber In Postwar Applications

EXAMPLES of how synthetic rubber can bring about improvements in postwar product designs, were pointed out recently by W. D. Parrish, Technical Service Manager of the Hycar Chemical Company.

From the standpoint of synthetic rubber as an engineering material, there are many applications where better performance of machinery can be expected. The oil and abrasion resistance of the synthetics make possible their use as a lining for motor bearings which operate in oil. When mixed with paper pulp, synthetic rubber can be rolled into thin sheets which are water and moisture proof. Thick sheets of this mixture can be used as artificial leather. When paper or cardboard is impregnated with synthetic rubber, the resulting material has good qualities of strength, toughness and durability. Fabrics impregnated and coated with synthetics may well have many advantages for a number of economical and important industrial applications.

Many possible applications of synthetic rubber in the postwar automobile may lead to the production of a vehicle that is marketly superior to prewar models because of the oil and heat-resisting properties of many of these materials. One of the aims of designers of postwar automotive vehicles is a passenger car which will run 40 to 50 miles on a gallon of gasoline. Boiling and freezing of radiators may be eliminated by sealing the cooling liquid in the cooling system. Greater power, efficiency and economy could be obtained if the engine operating temperature should be raised 100 deg.

Drawn Box Shapes Of Various Aluminum Alloys

THOMAS H. HAZLETT
Structures Research Laboratory, Lockheed Aircraft Corporation

Various factors which influence the forming limits of box-type parts drawn from various aluminum alloys are discussed. Design rules are given for boxes, with and without flanges, and having square and round bottom corners. Recommendations for limiting depth and corners based on the results of tests are included.

FORMING box shapes by drawing has been practiced for a long time, yet the mechanics and limitations of the process are little understood today. Virtually all dies for drawing boxes have been constructed by the trial-and-error method. Little experimental work appears to have been done in establishing forming criteria useful to industry in general. The investigations described in this article were conducted to establish the forming limits of aluminum alloy parts, other than cups, on a sound engineering basis.

To conduct a series of experiments in which the final depth of the drawn parts would not be limited by the dimensions of a die, but rather where blanks of various sizes could be drawn entirely into the die, two bottomless draw dies were made of Kirksite to form 6x6 in. boxes with round corners. One die was for a box having a corner radius of 5/8 in., the other for a box having a corner radius of 1½ in. The bottom radius on the punches was 5/8 in. for both dies.

Preliminary tests were made to determine the effect of blank shape on maximum depth. Results of the tests indicated that a circular blank was close to the optimum shape for both dies when a final depth greater than about 3 in. was required.

Blank sizes varying in steps of 0.5 in. in diameter were then prepared from 24SO, 52SO, 53SW, 61SW, 52S1/2H, and 3SO aluminum alloy sheets. Using minimum hold-down pressures to prevent wrinkling, increasingly larger blank sizes were formed on each die until failure of the part occurred. Test conditions were then checked to insure that extraneous factors such as excessive hold-down pressure, improper lubrication, or eccentric positioning of the blank did not contribute to failure.

Three parts were then drawn from the largest blank size which did not fail in forming. The parts were used to establish the "limiting" depth for any one run on the press. This procedure was usually repeated several times for each alloy tested. The possibility of relying solely on material with unusually good forming characteristics when establishing the limits was thereby minimized. It was frequently observed that failures would occur toward the end of the draw, often near the top of the part.

Values obtained from these tests were mathematically reduced to values corresponding to a box having square corners on the bottom, by use of the formula

$$h = H - 0.43\, r_p$$

in which h is the depth of drawn box having square corners on the bottom and having no flanges, H is the actual depth of the drawn box when the blank is drawn completely into the die, and r_p is the bottom radius on the punch.

Limiting depths determined from these tests are given in Table I. The column marked "Maximum" gives the maximum depth part which was obtained for any given material, while the column marked "Limit" is the depth below which no failures occurred for any given material.

Forming Limit Factors

1. EFFECT OF MATERIAL VARIATION. Deviation between the maximum and limiting depths given in Table I for either die must not be overlooked. Since the test conditions were similar except that the blanks were cut from different material each time, the difference in depths must be attributed to material variation. While this variation is particularly pronounced for the boxes of 1½ in. radius from 24SO Alclad, and for the boxes of 5/8 in. radius from 52SO, some variation is indicated for most materials.

It is of interest to note that another series of tests on drawn cup shapes indicated a variation between maximum and limiting depths of 18 percent for 24SO and 13 percent for 52SO, while the variation for drawn boxes shown in Table I is 73 percent

Table I—Limiting Depths of 5/8 in. and 1½ in. Corner Radius Boxes

Based on 3 to 12 tests of each size of blank. Results given here are in terms of boxes having square corners on the bottom without flanges.

Material	Depth of Box, in.			
	5/8 in. Radius		1-1/2 in. Radius	
	Max., in.	Limit, in.	Max., in.	Limit, in.
24SO	3.8	3.1	5.2	3.0
52SO	6.1	4.2	5.2	5.2**
53SW	2.1	2.1	3.2	3.0
61SW	2.1	1.6	3.0	2.7
52S1/2H*	...	3.7***	...	...
3SO*	4.8	4.4	...	...

*Results based on one press run only.
**Based on two small runs only.
***Deepest part formed—limit not determined.

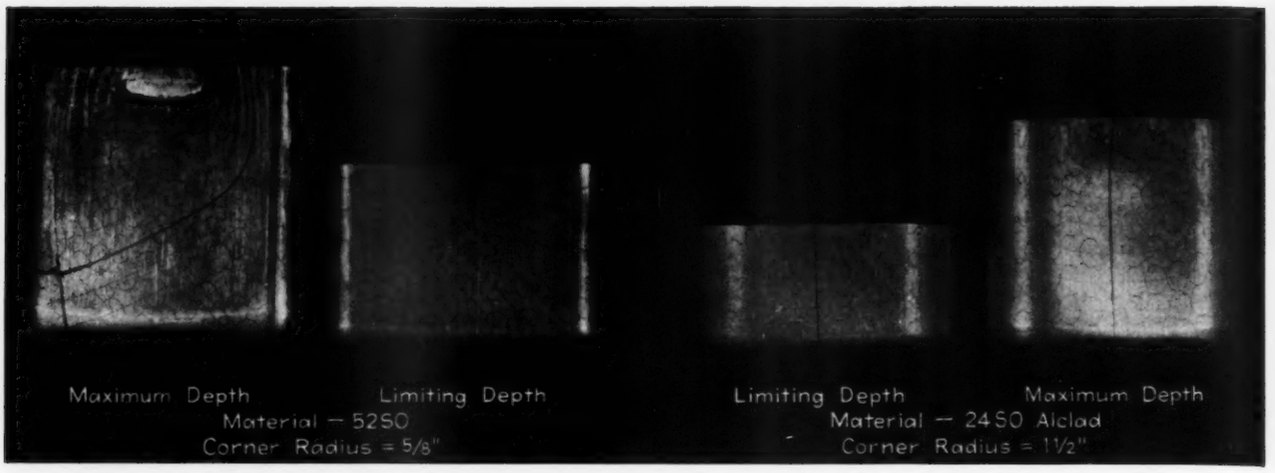


Fig. 1—Drawn boxes indicate the effect of material variation on limiting depth

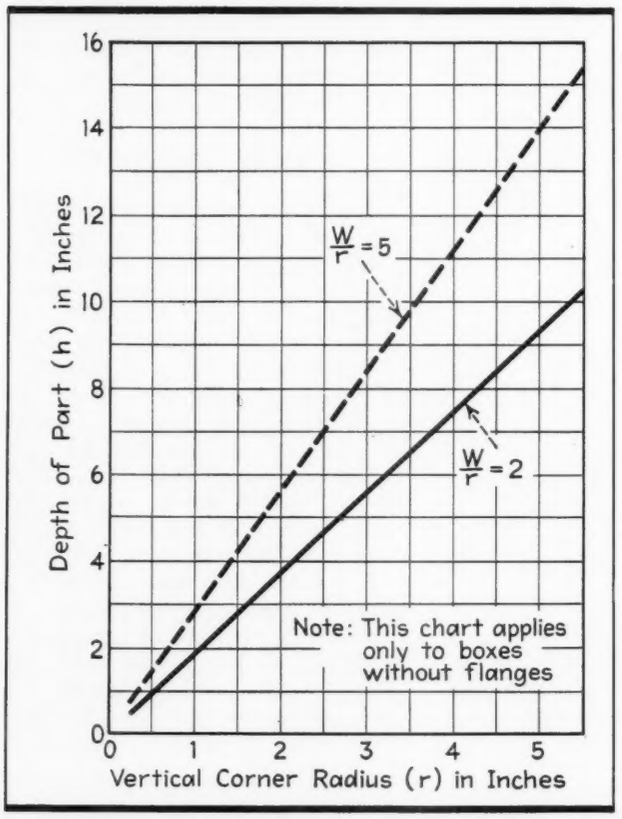

Depth of Part (h) in Inches
Vertical Corner Radius (r) in Inches
W/r = 5
W/r = 2
Note: This chart applies only to boxes without flanges

Fig. 2—Limiting depth of boxes drawn from 24SO Alclad

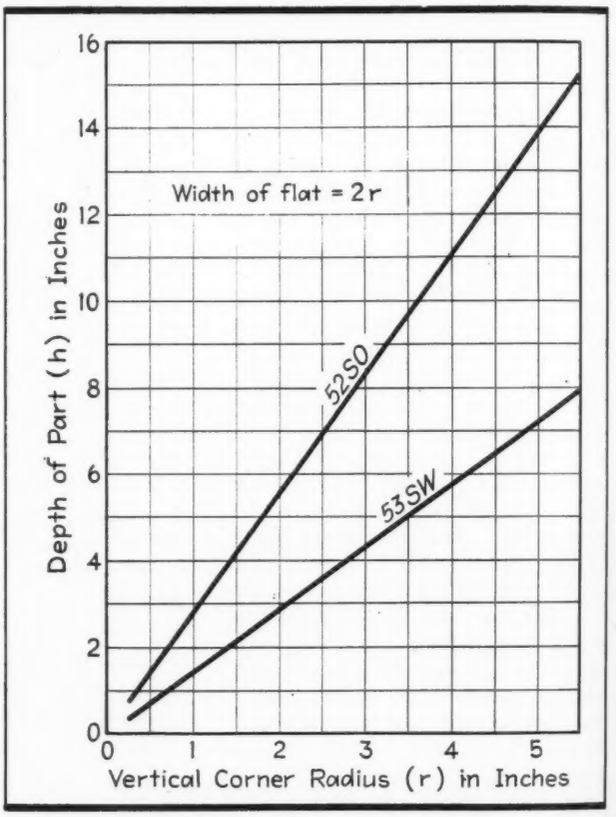


Fig. 3—Limiting depth of boxes drawn from 52SO and 53SW

for 24SO and 45 percent for 52SO. Thus it appears that boxes are more sensitive to material variation than drawn cups.

Absence of large variation for most of the other materials in Table I indicates the particular material used in the tests was quite uniform, but this might not hold true in normal production. In other words, the values given as the limiting depth are not necessarily the true limiting values but are the limits obtained on the particular tests made. The probable true limiting depth could only be ascertained after a large number of tests were made which would permit application of the laws of probability.

Within the limits set by available test data, the limiting depths given in Figs. 2 and 3 are conservative for drawn boxes of 24SO Alclad, 52SO and 53SW in which the corner angles do not exceed 90 deg., and the corner radius r does not exceed half the width W of the flat side measured as the distance between tangent points of two adjacent corner radii. For boxes drawn of 24SO Alclad somewhat more liberal limits, as indicated by the broken line in Fig. 2, may be used when W/r is equal to or greater than 5. These values must be used with caution and only after a thorough consideration of all the factors which influence the forming limits of box-type parts.

2. Effect of Width of Flat. This factor can be explained by an analysis of Fig. 4. The blank was photoprinted with a combination square and circle grid pattern before forming. In Fig. 4 the resultant drawing strains can be seen, with the typical severe

combined tensile and compressive strains in the corners. Also, it can be noted that the deformations extend beyond the point of tangency of the corner radius into the flat side of the box. As a rule, the deeper the part, the greater the deformation occurring in the side of the part. It may be observed that the compressive strains in the corner of the box are relieved by compression in the flat sides adjacent to the corners. This is substantiated by the fact that the compressive strains in the corners tend to reach a maximum value at about 2.5 in. from the bottom of the part, although the tensile strains continue to increase till near the end of the draw. The total shearing strains, during the drawing operations, imposed on the blank at the corners are thus reduced.

It appears that the maximum depth obtainable in box parts having round corners depends in part on the ability of the material to transmit these compressive strains. Since slight variations in the mechanical properties of the material being formed may affect this process, greater variation in depth would be expected in box-type parts than in cups.

Consideration of this phenomenon also indicates that the width of flat area between corners is also an important factor. Since the two dies used for these tests have the same over-all dimensions (6x6 in.) but the corner radii differ, the width of flat also differs. The ratio of width of flat W to corner radius r equals 2 for 1½ in. radius boxes and 7.6 for ⅝ in. radius parts.

3. Effect of Corner Radius. The effect of the size of the radius on the limiting depth of a drawn cylindrical cup is well established. Although most data on cylindrical cups are given in terms of the index of r/R, conversion to h/r can be readily accomplished as stated previously. All results obtained to date indicate that a constant limiting value of h/r holds regardless of the size of the cup. Thus the depth decreases as the radius decreases.

On the other hand, test data indicate that for box-shape parts the ratio of h/r increases with a decrease in corner radius. Although this ratio increases, the depth still decreases with decreased radius, but at a reduced rate. This effect is most noticeable with corner radii less than 1.5 inches.

Thus it seems logical that at least the two ratios W/r and h/r must be considered in establishing the limits of drawn boxes. Since it is unlikely that material having minimum properties was encountered in the tests described except for the 24SO—1½ in. radius and 52SO—⅝ in. radius parts, no definite conclusions can be made regarding the relationship between these ratios. Fig. 5 shows one possible relationship based on the experimental evidence obtained to date. In drawing these curves the data were weighed in view of the material variation encountered; the greater the variation the more dependable is the lowest limiting value obtained. Inasmuch as no tests were made beyond the value W/r equals 7.6 the curve was broken at that point. But further analysis indicates that the curve must become horizontal at some value of W/r, that is, the values of h/r will probably not continue to increase indefinitely with increase of W/r. This curve is added only as a matter of interest and should not be used in design without a complete understanding of the approximations made.

4. Effect of Punch Radii. Several comparatively recent investigations, notably by S. Fukui (see "Researches on the Deep Drawing Processes," *Scientific Papers*, Inst. Physical and Chemical Research, Tokyo, Japan, Vol. 34,193, p. 1,422), and Swift (see "Deep Drawing Tests for Sheet Metal," *Journal*, British Inst. of Automobile Engineers, May, 1940, p. 361), have shown the importance of the size of the radius used on the bottom of the punch. Both men demonstrated a thinning of the blank which causes premature failure when this radius is too small. Swift found that the limiting depth increased with increased radius until a complete hemisphere was obtained. This same action undoubtedly occurs in box-type parts.

One important factor in box-type parts, particularly when small radii are used on both the corners and bot-

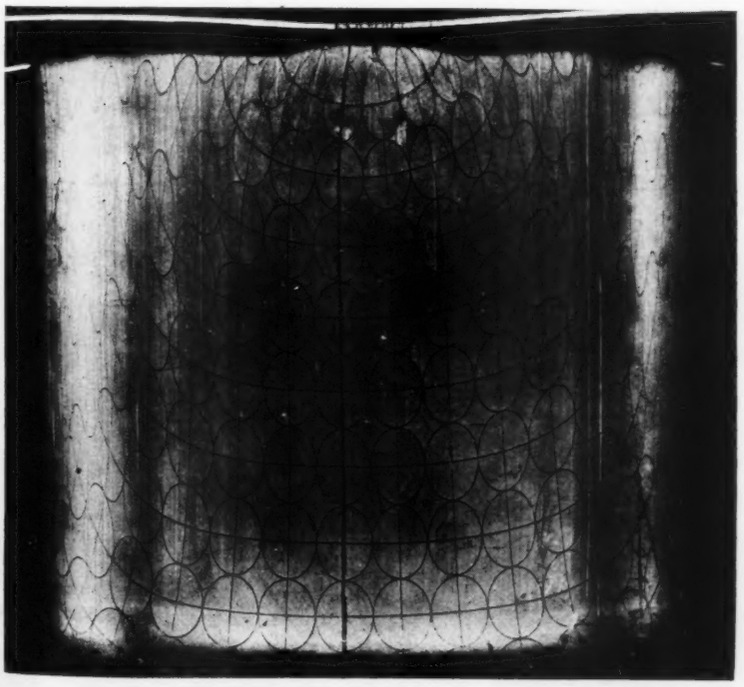


Fig. 4—Side of a box after drawing. Distortion in combination circle and grid pattern, applied before forming, shows the resultant drawing strains

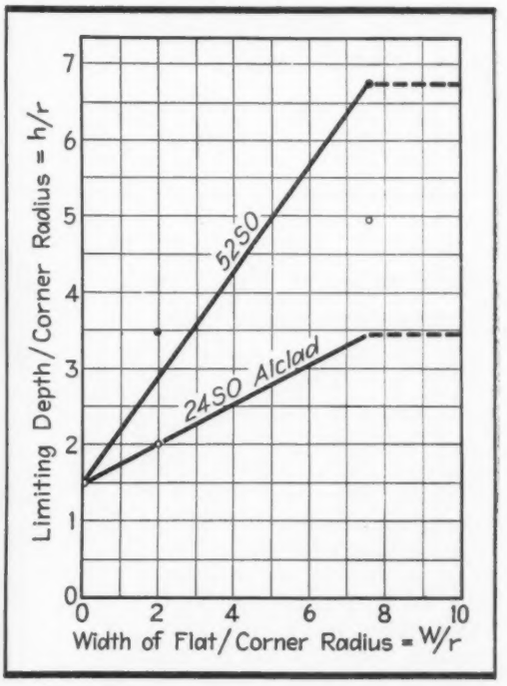


Fig. 5—Relationship between corner radius, width of flat and limiting depth of drawn boxes

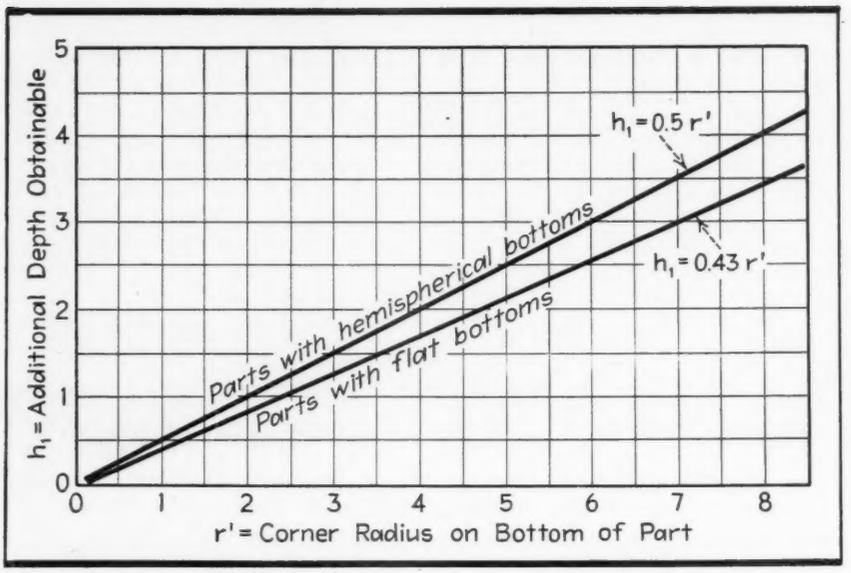


Fig. 6—Increase can be obtained in depth of part by using a bottom radius instead of a square corner because a radius reduces blank size required for a given part

tom, is the size of the spherical radius used on the bottom corners. The greatest tensile stresses are imposed on this portion of the blank since it supports the greater portion of the load required to draw the part at the corners. An increase of the spherical radius at this point will aid in distributing the imposed load, thereby preventing excessive thinning of the material which may result in premature failure at that point. An additional gain in the final depth can be realized since a large radius will reduce the blank size required to draw a given size part.

5. Effect of Flange. If the limiting depth is given for a particular part and a flange is required, the final depth will be reduced by an amount equal to the flange width. This rule is true for all materials and shapes which fail near the beginning of the draw. But since box-type parts frequently fail in the latter half of the draw, it may be possible to obtain a part having a final depth almost equal to the limiting depth and still have flanges on the part. The additional depth which can be obtained in this manner has not been ascertained.

6. Effect of the Die Clearance on Limiting Depth. In box-type parts there appears to be considerable thickening of the side wall of the part during forming. This is apparently caused by the compressive strains which feed in from the corners and are not relieved by a corresponding tensile strain, thereby causing thickening of the flat wall of the part.

This same compressive action will cause "canning" of the side of the box when thin material is formed if the die clearance is not properly adjusted. One method of preventing this distortion is by adjusting the die clearance to provide some "ironing" of the sides in the latter portion of the draw. This tends to prevent thickening of the material, thereby confining the compressive strains to the corners of the part. When very close tolerances are required on such a part, some ironing is required and this will increase the limiting depth.

Design Procedure for Boxes

The limiting final depth H of a box-type part can be computed as follows:

1. Determine the limiting depth h from Figs. 2 or 3 for the corner radius required.

2. Determine the additional depth h_1 from Fig. 6 which can be obtained by using a punch radius.

3. Determine the decrease in depth required when forming a flange of width F on the part.

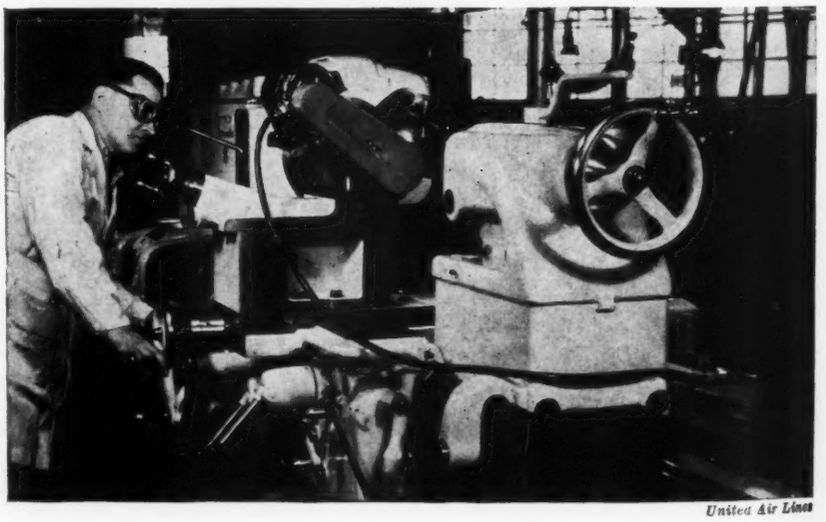
The limiting final depth H is

$$H = h + h_1 - F$$

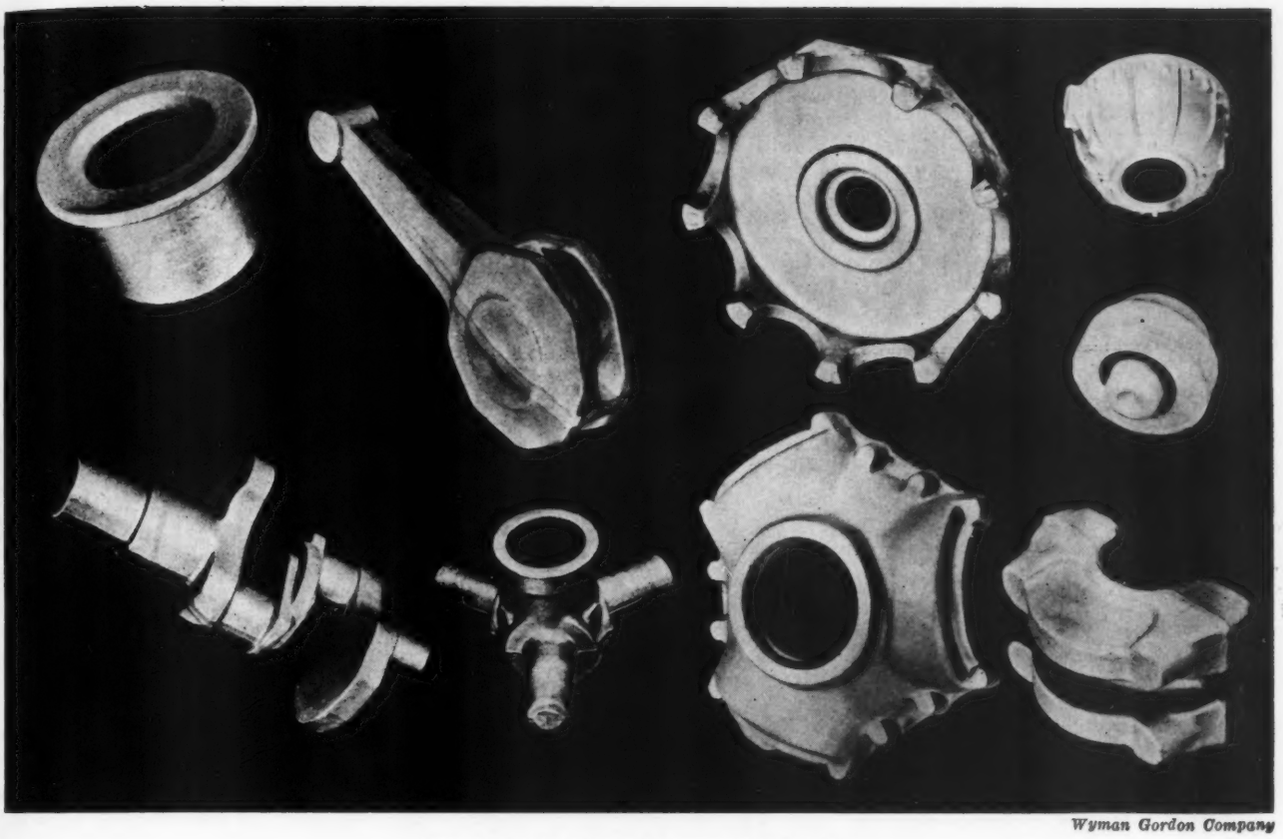
Since little is gained by the addition of h_1 when the punch radii r', Fig. 6, are small it is recommended that this factor be ignored when r' is less than 0.5 in. It must be noted that Figs. 2 and 3 do not apply for corner angles greater than 90 degrees.

Dimensional Painting Decreases Accidents

THREE - DIMENSIONAL painting, developed by DuPont, has been adopted by United Air Lines for its machine shops. This painting method produces light reflections which emphasize safeguards and spotlight points of operation on machines. Operational parts of a lathe are painted buff, safeguards are in orange, and the balance of the machine is gray. The system lessens eye fatigue, decreases accidents and increases efficiency. An article, "Color for Efficiency," was presented in the January, 1942 issue of Product Engineering.



United Air Lines



Wyman Gordon Company

Fig. 1—Typical drop hammer die-forgings

Advantages and Limitations Of Die-Forged Machine Parts

CHARLES L. TUTT, JR.
Princeton University

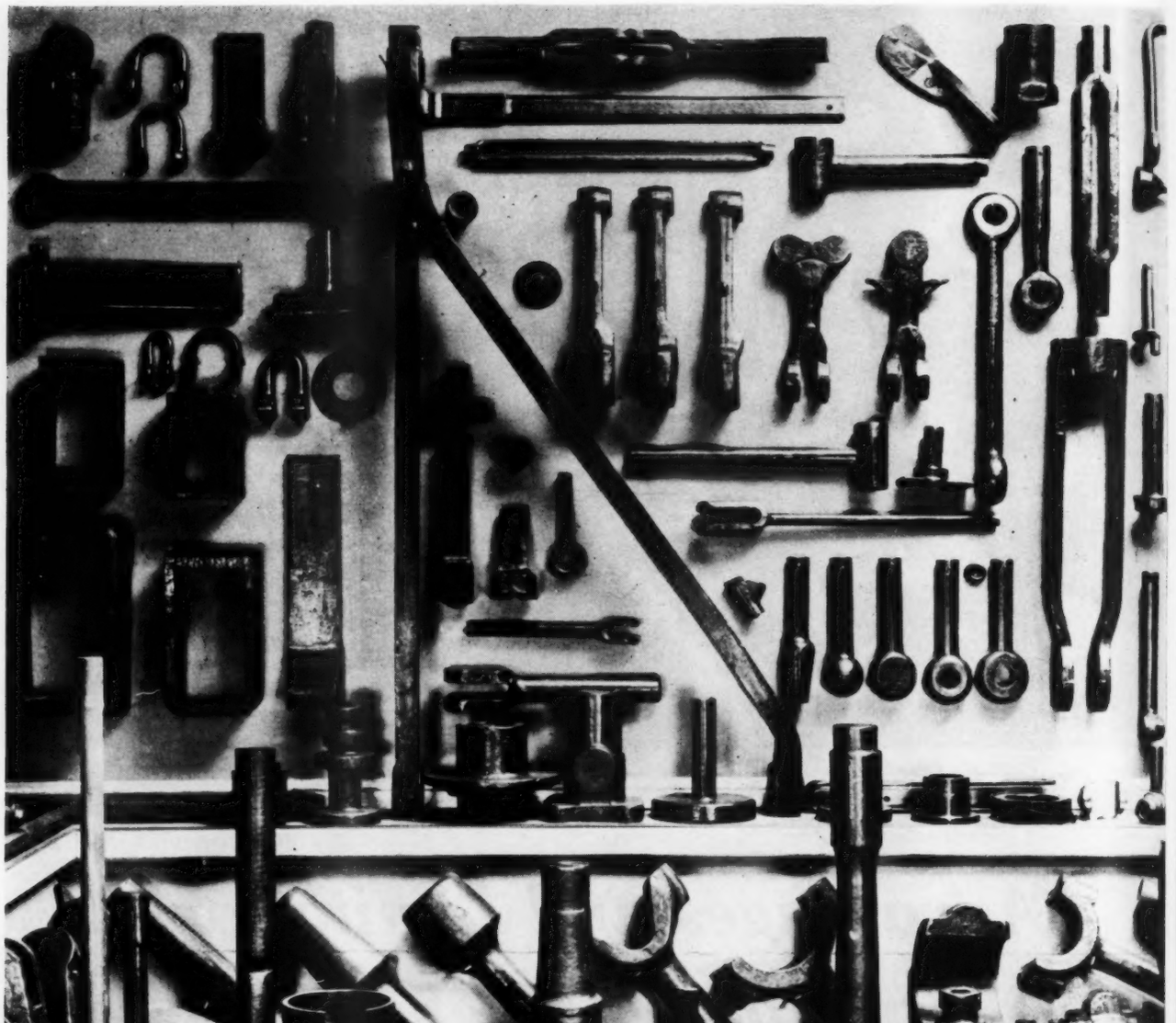
When to specify die-forgings, what type to specify, how to design all types of die-forgings, and design rules are reviewed and summarized. Production factors that must be considered to make the design economical and easy to forge are presented. Effects of recent developments in forging machines and dies are described.

BEFORE selecting die-forging as a method of fabricating machine parts, experienced designers weigh a number of factors to be sure the part is adapted to production. Die-forgings have several advantages and some limitations in applications.

Chief among advantages in the selection of die-forgings is high strength. By the hot working of the material and control of grain structure and flow lines it is sometimes possible to increase strength of the material as much as 100 percent. This additional strength is often valuable in withstanding impact stresses exceeding tensile and compressive loads for which a part is designed since elasticity in the grain structure enables the part to recover without causing permanent distortion. Advantage can be taken of high strength to reduce size and weight of a part, which may be of value in conserving space or power, as in aircraft parts, or saving material.

Saving in material is further augmented by the fact that dimensional tolerances can be held, as a rule, within much closer limits than in a sandcasting. Thus, in general, much less metal need be removed by machining, unless the part must be hollow or unless the comparison is made with permanent mold castings which can be held to about the same tolerances as forgings. There is small waste in die-forging flash as compared to casting sprues.

Smooth surfaces are obtained by die-forgings, particularly those that are coined, blasted or pickled. Coining brings surfaces to normal machin-



National Machinery Company

Fig. 2—Most of these die-forgings are produced by upsetting

ing tolerances of 0.001 in. or even closer. The ability to produce parts rapidly with small dimensional variation is an important consideration in large scale production. Die-forgings have qualities that reduce machining time and cost, and decrease removal of metal.

Die-Forging Methods

Methods employed to manufacture die-forgings are classified according to the machine upon which they are made.

1. Hammer die-forgings are formed by impact of dies on the metal to be forged in either a steam-drop or board-drop type machine. Parts requiring considerable drawing are produced by the former, parts of small size or flat, thin shapes by the latter. The principal advantage of hammer die-forging over other methods of die-forging is that it is possible to have multiple impressions in a die-block and that, with rapid blows, bar stock can be worked into a finished forging without reheating. In most hammer die-forging, round-cornered square stock, which is the cheapest shape produced by the rolling mills, is employed. Use of round stock is limited by higher cost.

2. Press die-forgings are formed by pressure of the dies in hydraulic and mechanical (crank) type machines. A slug of hot metal of suitable diameter and length, when placed in the die impression is forced by pressure to flow and fill the die cavity. Parts are completed in one or more operations. No preliminary operations, such as those performed by edger and blocker hammer die impressions, can be accomplished.

3. Upset die-forgings are formed when bar stock, gripped between two dies, is shortened axially when struck by a heading tool in a mechanical (crank) press. The method is usually

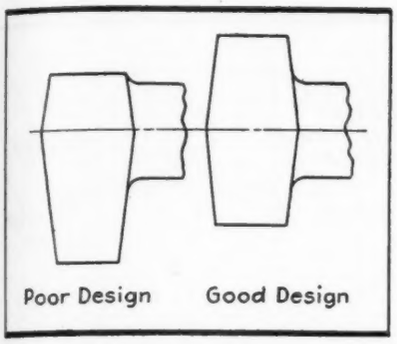


Fig. 3—Design die-forgings with metal volume on one side nearly equal to that on other side of parting line

used for round or circular parts made from bar stock.

4. In addition there are four special forging machines: The swager, bulldozer, forging rolls, and cold-forging machines.

(a) Swaging operations are performed by a rapid succession of impacts in a rotary type machine and are limited to reducing wire, bar or tube of any standard cross-section to a smaller, and usually circular cross-section. In its particular field, the swaging machine is without competition, since it produces work rapidly and within close dimensions. It is adapted, however, to parts of small diameter.

(b) The bulldozer is either a crank or hydraulic type machine in which pressure is applied to the dies, generally for bending operations.

(c) Forging rolls are employed to flatten, neck or otherwise reduce one or more dimensions of the stock under the influence of pressure exerted by rolls or semicircular dies having grooves of appropriate shape. Forging rolls have many applications in which a reduced straight or taper section is produced, and are often used to perform preliminary operations for upset and hammer die-forgings.

(d) Cold-forging. Progress has been rapid in the field of cold die-forged parts, especially in cold-heading machines, which are a form of upsetting machines. Great savings have been made in producing headed or flanged parts similar to those made by screw machines.

When to Use Die-Forgings

The most important factor determining whether a die-forging should be used is that the process is one for mass production, since die cost is too high for small production. The minimum quantity of die-forgings that is economically feasible depends, as a rule, upon the cost of necessary dies.

Size of the part is another factor determining the choice of the die-forging process. Small die-forgings weighing a fraction of an ounce, can be made as press die-forgings. Small upsetting machines and swaging machines excel for small parts. Drop-hammers of small size however, are used mostly for silverware. Presses available today can be used to make die-forgings up to approximately 25 lb. Press and hammer size, die design, and the type of material are limiting factors. The largest steam drop-hammer commercially available has a rating of 50,000 pounds, and for the board drop-hammer a maximum rating of 5,000 pounds. Such hammers are rated by the falling weight of their moving parts. Upset die-forging machines are rated according to the largest stock diameter the machine can handle, which is now 9 inches.

The character of material to be used plays an important part in the selection of die-forging processes. Common forging materials are steel and steel alloys with 0.1 to 0.5 percent carbon, copper and copper-base alloys and aluminum alloys. Parts designed of materials other than these do not, in general, lend themselves to die-forging.

In general, carbon steels are lowest in cost and are the easiest ferrous materials to forge. Low alloy steels rank next in cost and ease of forging, and the higher alloy steels are highest in cost and, as a rule, are hardest to forge.

Rules for Die-Forging Design

RULE 1, Draft: Allow sufficient draft to facilitate removal of the forging from the die but not so great as to unduly increase machining costs. Table II gives "normal" draft angles.

In many instances a draft angle that is less than the "normal" angle can be used. However, this requires more care of the dies, and die wear is accelerated. It is advisable to specify more than a 10-deg. draft angle if satisfactory die-forgings are to be procured on machines 20 years old. At the other extreme are modern hammer-forging machines on which draft angles as small as 1½ deg. are practicable. Selection of the optimum draft angle necessitates a knowledge of the equipment. There are instances, however, when a small draft angle may materially reduce machining costs and more than offset extra die costs.

RULE 2, Parting line: Design forgings, if possible, so that approximately equal volumes of metal are at each side of the parting line, and so that the die can be parted in one plane. Where a one-plane parting is

Table I—Steel Forging Materials

S.A.E. No.	National Emergency Substitute	Use and Remarks
1020		Small forgings. Physical properties are low. Simple normalizing of forging required
1030		Small forgings. Physical properties better than 1020
1035		Medium-sized forgings. Physical properties moderate. Good machining properties
1040		Small and medium-sized forgings. Fair machining properties
1045		Large forgings. Avoid thin sections for heat-treatment
30905 30915		Corrosion and heat-resisting forgings. Difficult to machine. Do not respond to heat-treatment
4140	NE 1345 NE 9640 NE 9440	Aircraft forgings. Caution required in quenching thin sections
6145 6150	NE 1350 NE 9645 NE 9445	High fatigue strength forgings. Ideal for parts subjected to serve conditions
3245 3250	NE 9650 NE 9450	High strength forgings. Most suitable for sections more than 1½ in. in diameter because of greater penetration of heat-treatment
3450	NE 8949	Large high-strength forgings
5140	NE 1340 NE 9435 NE 9635	Forgings requiring strength and toughness. Not recommended for water quenching. Used for gears and axle shafts
2340 3140	NE 1345 NE 9642 NE 9442	Forgings requiring strength and toughness. Used for gears and axle shafts

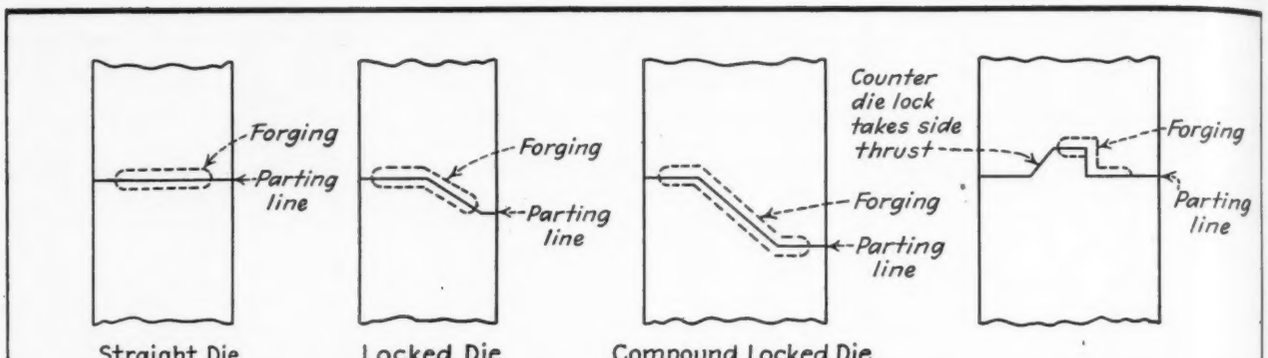


Fig. 4—Types of forging dies. Straight dies are preferred when possible

Table II—Draft Angles

Machine	Normal Draft Angle, deg. External Surfaces	Normal Draft Angle, deg. Internal Surfaces	Remarks
Board Drop Hammer	7	10	Modern machines can go as low as 5 deg.
Steam Drop Hammer	5 1/2	7	Modern machines can go as low as 1 1/2 deg. Older machines require more draft.
Upsetter	3	5	Draft required only on deep dies with narrow pockets.
Press	0 to 3	0 to 3	May be designed without draft as parts are ejected, when dies open, by knockout pins.

not feasible, design for the simplest irregular parting.

When the parting line requires one change of plane, locked dies are used. If a locked die has more than one change of plane it is called a compound locked die.

When locked dies are used, the parting must be designed to remove side thrust which results when the parting is not in a plane at right angles to die motion. On difficult parts die side thrust is taken by so-called "counter die locks," as in Fig. 4.

All upset forging and most press forging dies are "straight" dies. Hammer forging dies often have to be of the loaded type but "straight" die partings are preferred because they cost less and are likely to have lower maintenance cost and few complications in forging.

RULE 3, Fillets: Avoid all sharp inside corners and all sharp exterior edges and corners. Sluggish flow of any metal makes it virtually impossible to die-forge a part with a sharp corner or edge. Fillets that are too small result in die cracks and reduce die life. In hammer die-forgings, fillets commonly run from $\frac{3}{64}$ in. minimum for small die-forgings, to $\frac{1}{8}$ in. minimum for hammer die-forgings of 100 pounds. Upset and press die-forgings require the same radii and fillets as for hammer die-forgings.

One important consideration in the use of fillets is the effect of cutting across the grain structure when machining a fillet to a smaller radius. Fig. 5 shows the desirability of small fillets in retaining favorable grain structure. If a square or nearly square corner must be machined, fewer flow lines will be cut if the corner radius is small than if it is large, hence the part having the smaller corner radius initially will be the stronger.

RULE 4, Changes in section thickness: Avoid all abrupt changes in section thickness. Since thin sections cool faster than thicker ones, heavy shrinkage stresses are apt to be set up where abrupt changes in section thickness occur.

RULE 5, Thin sections: Avoid sections that are too thin to be forged readily. Although sections $\frac{3}{32}$ in. thick can be produced satisfactorily in hammer die-forgings of moderate size, a minimum thickness of $\frac{1}{8}$ in. is preferred. When even this minimum is specified, however, warpage is likely to occur during the cooling. Consequently, straightening operations usually are needed before machining can be done. High carbon and alloy steels particularly are difficult to die-forge when thin sections are specified.

Thin walls on die-forgings have a tendency to freeze in the die. This results in high scrap losses and increases cost because of the extra care required. Cracks are also apt to occur during heat-treatment because internal strains are set up by quenching. This is especially true of high carbon steels and certain of the alloy steels.

RULE 6, Location points for machining must not be close to die partings. If they are, die wear will result in a constantly changing position. The

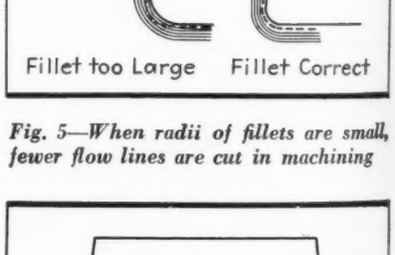


Fig. 5—When radii of fillets are small, fewer flow lines are cut in machining

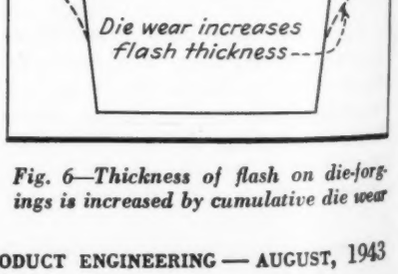


Fig. 6—Thickness of flash on die-forgings is increased by cumulative die wear

proper position for locating points can be determined by a careful consideration of the way the part must be held while being machined, and of those dimensions that must be held within close limits.

RULE 7, Finish: Allow sufficient material for machining at all points where finishing is necessary. Allowance for machine finish ranges from $\frac{1}{32}$ in. for small hammer die-forgings to $\frac{1}{16}$ in. for large hammer die-forgings, and is not an over-all allowance, but should include the amount of metal to be removed from each surface to be machined.

Upset die-forgings can be held to such dimensions that an allowance of $\frac{1}{32}$ in. for finish is sufficient, as a general rule, and even less allowance is permissible when modern machines are employed. For press die-forgings $\frac{1}{32}$ in. or less allowance for finish is sufficient.

Many die-forgings are coined cold, that is, are brought to the finish dimension by striking between a pair of dies made especially for this purpose. Coining not only approximates the finish attained by machining but over-all tolerances of less than ±0.001 can be held on bosses and other similar parts of die forgings. Fig. 7 shows recommended finish allowances.

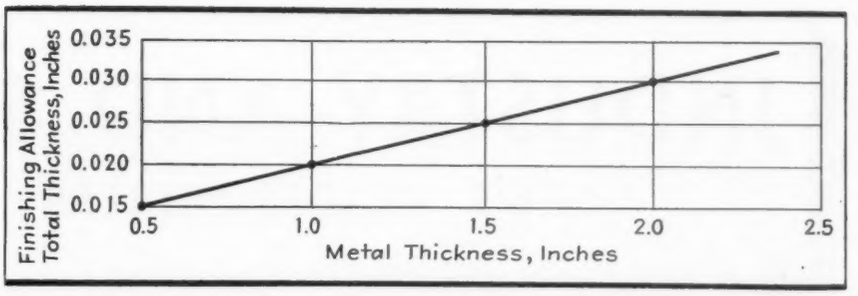


Fig. 7—Finish allowances for coining operations (Chevrolet Draftsman's Handbook)

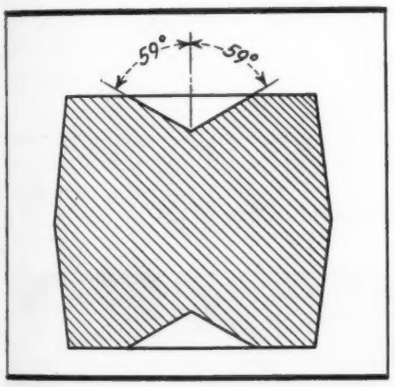


Fig. 8—Method of spotting a drilled hole by the die parallel to die motion

RULE 8, Spotting for drilling: Where large holes are to be drilled in forgings parallel to die motion, it is usually well to specify that the holes be spotted by the forging dies.

Fig. 8 shows how a simple forging is spotted for drilling a central hole. Holes smaller than ½ in. in diameter are not usually spotted by the die. Even though drilling is to be done from only one side of the forging, spots are placed on both sides of the piece. This is done partly because a more favorable grain flow is secured and to bring the grain flow lines closer together. Where close center distances are required, such as the distance between crank pin and piston pin holes in a connecting rod, only one of the holes should be spotted unless the forge shop can guarantee that hole centers will come within required limits.

RULE 9, Grain size: Specify that the material used in the forging have a fine grain, especially when the material is steel and is to be subjected to heat-treatment. Large grain size is a common cause of quench cracks, which are often regarded as a fault of the forging process rather than of the material. Grain size always increases with heat-treatment.

RULE 10, Cleaning: Specify that die forgings be furnished free of scale, which impairs tool and cutter life. Forgings to be subjected to fatigue-producing stresses should be freed of scale by shot-blasting rather than pickling, which has a tendency to open up hair cracks unless carefully controlled.

Shot-blasting costs more than pickling and requires special equipment. Most forge shops have facilities for pickling but few have shot-blasting equipment.

RULE 11, Deep pockets should be avoided and recesses should be as simple in shape as conditions permit. The largest radii possible should be used at the bottom of all pockets and recesses unless the surfaces involved are to be machined. Recesses of simple shape are easier to die-forge, easier to clean and reduce die wear and cost.

RULE 12, Identification marks: Locate on unmachined surfaces with consideration of minimum die cost and upkeep. Identification marks should be placed to allow the use of an insert in the die.

Further rules applying specifically to the different types of die-forgings will be presented next month.

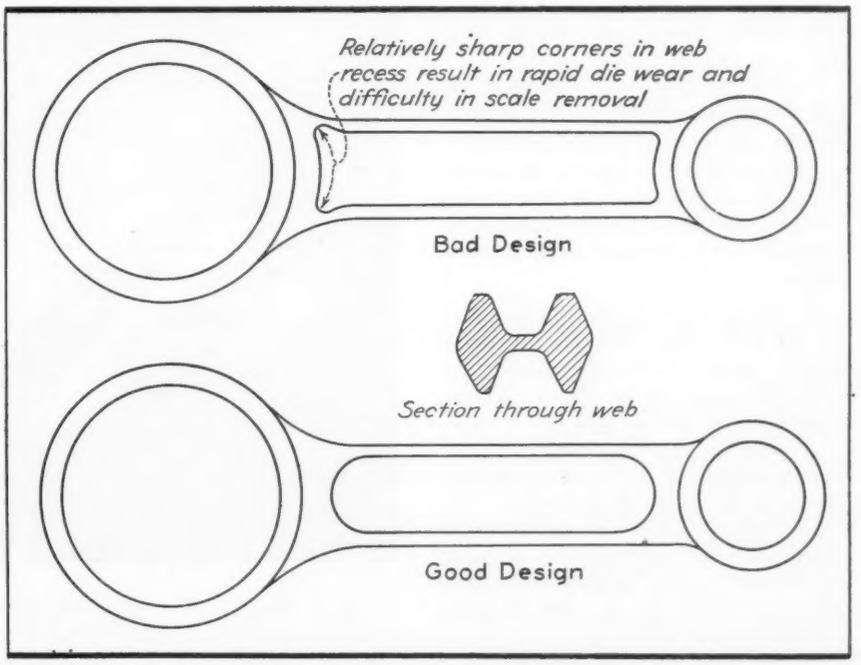

Relatively sharp corners in web recess result in rapid die wear and difficulty in scale removal
Bad Design
Section through web
Good Design

Fig. 9—Recesses of simple shape are easier to produce and help minimize die cost

INDUSTRY AND SOCIETIES

NEWS • READER LETTERS • MEETINGS

War Machine Not Oversupplied, Research Institute Survey Indicates

TAKING ISSUE with groups which have recently begun to insist that America's war machine is oversupplied, Leo M. Cherne, executive secretary, and Leon Henderson, chairman of the board of editors, of the Research Institute of America in a joint statement recently indicated there is no oversupply, and that war procurement will show little, if any, let up for the next year, barring a sudden collapse of Germany, a factor not contemplated in the present procurement program and plans.

The statement was based on a special study made by the Institute executives with the cooperation of the military officials responsible for war procurement. The survey definitely indicates that:

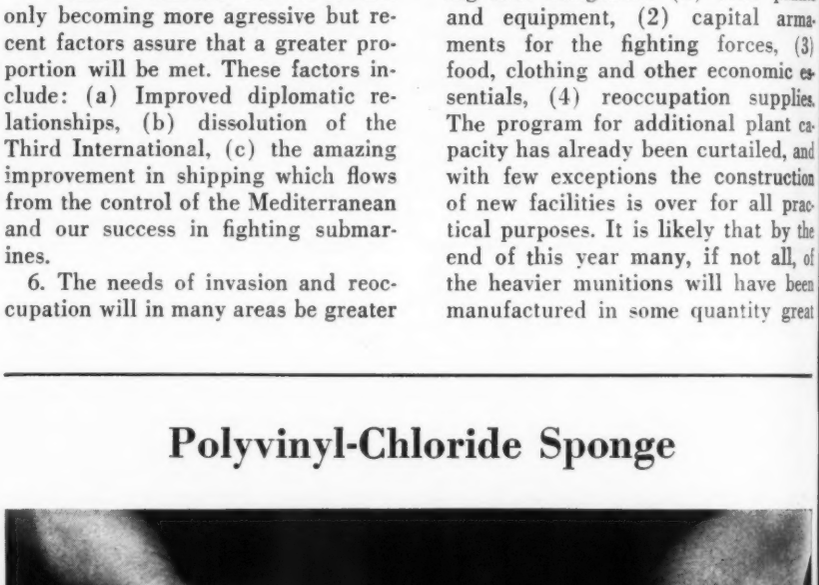
1. There is no general oversupply.
2. There are some limited areas of oversupply which may change with invasion.
3. War procurement will show little change in volume for the months ahead.

The following factors in the survey brought out the conclusion that there will be an enormous and continuing demand for production of war materials:

1. While American troops in action in the main have been properly supplied, most divisions-in-training or awaiting embarkation in the United States are not fully equipped.
2. Allied requirements are growing. They assure war production expenditures at continued high levels.
3. Aid to China in the form of munitions and supplies will multiply each month, particularly with shipping available for the first time in recent weeks.
4. Mexico's request for $400,000,000 worth of used machinery represents a sizable withdrawal from our community.
5. Russia's demands for aid are not only becoming more agressive but recent factors assure that a greater proportion will be met. These factors include: (a) Improved diplomatic relationships, (b) dissolution of the Third International, (c) the amazing improvement in shipping which flows from the control of the Mediterranean and our success in fighting submarines.
6. The needs of invasion and reoccupation will in many areas be greater than those of initial supply. This will represent an important part of continuing production demands.

Both Cherne and Henderson, stressed the fact that the probabilities in the production program for the duration differ in each of the following four categories: (1) New plants and equipment, (2) capital armaments for the fighting forces, (3) food, clothing and other economic essentials, (4) reoccupation supplies. The program for additional plant capacity has already been curtailed, and with few exceptions the construction of new facilities is over for all practical purposes. It is likely that by the end of this year many, if not all, of the heavier munitions will have been manufactured in some quantity great

Polyvinyl-Chloride Sponge



Sponge made of Koroseal, the plasticized polyvinyl chloride developed in the B. F. Goodrich Co. laboratories, is now being used in many essential industrial applications. Since the material cannot be vulcanized like rubber, special forming was devised, using a new synthetic ingredient.

enough to meet the Army's needs. The demand of the military for food will continue to increase with the continued growth and activity of the Army and Navy, although there are undoubtedly examples of excess inventories in some foods. Reoccupation of the captured territories will bring a demand for all the essentials needed to establish basic minimum economic life on the scorched earth left in the wake of the enemy's withdrawal from such areas.

Free License Granted For Use of Mareng Cell

USE OF PATENTS covering the Mareng cell has been granted to the U. S. Government under a free licensing arrangement by the Glenn L. Martin Company. The free license is for the duration only, with full rights reverting to the company in the post-war period. The Mareng cell is a synthetic-rubber fuel tank used for airplanes and other conveyances. Its most spectacular version is the self-sealing gasoline tank used in airplanes. A more recent application has been for turning box cars into tank cars for transporting oil and fuel. This principle can also be applied to other types of conveyances. Glenn L. Martin, president of the company, pointed out that the license had been granted "in the interest of hastening victory."

Ammunition Processing Patent Presented to U.S.

TO EXPEDITE the substitution of steel for brass in the production of military cartridges, a gift has been made to the United States Government by the Western Cartridge Company of a patent covering the processing of ammunition parts made from "non-directional" steel. This action makes available without charge to all ammunition manufacturers a process designed to speed up the changeover from brass to steel in producing cartridge cases by the cold-draw method, thereby saving large quantities of brass.

In many instances the same equipment for drawing brass cases can be adapted readily to the drawing of non-directional steel cases. By coating a sheet of non-directional steel top and bottom with 10 percent of copper alloy, five times the number of bullet jackets can be produced without increasing the consumption of copper over previous amounts.

The "Kitchen of Tomorrow"

Glass and plywood are the principal materials used in the construction of the "kitchen of tomorrow" created by H. Creston Doner, head of the design department of the Libbey-Owens-Ford Glass Co., which recently announced the innovation. Everything is arranged for maximum convenience. The working surfaces can be adjusted to any desired height. When not in use, all the units are covered by flat-surface tops which when folded back, automatically turn on fluorescent lighting units that light up the working area. The electric oven has a glass cover that is opened and closed by an electric motor. A motor-operated barbecue spit is also provided. The electric cooking unit has everything built in that would normally be used in cooking. Even automatic timing controls are provided. Pots and pans are eliminated because cooking is done in serving dishes. Sink faucets are controlled by pedals in the floor. A combination refrigerator and china-closet unit separates the kitchen and dinette. The refrigerator, which has four times the capacity of a normal unit, is divided into compartments each with its own controls. The ideas presented in this design are by no means final. The company made up the unit described to show some of the things that can be done with glass in the post-war kitchen.

Discussions and Comments From Readers

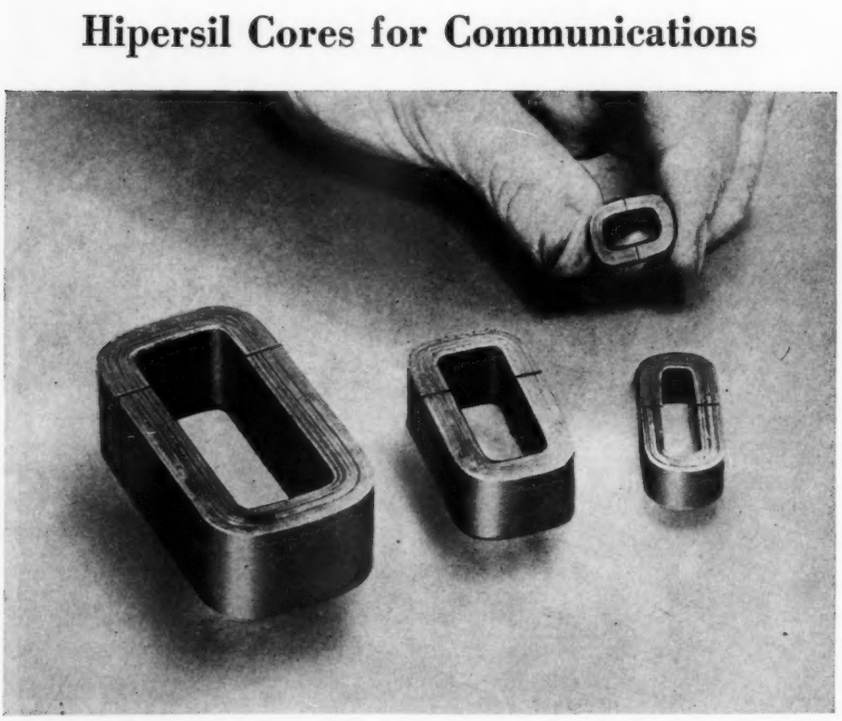
HAGENBOOK ARTICLE PRAISED BY BRUCKNER

To the Editor:

The article by L. D. Hagenbook in your May issue, Page 300, entitled "Impact Loads Determined by Brinell Technique" is extremely interesting. The suggested method would fill an urgent need, as soon as it could be established in the confidence of engineers responsible for avoiding part failures. However, the question of resistance to plastic yield versus time of loading should not be dismissed too lightly. The author states, on page 300, "Tests made by the author with a Brinell machine to measure the effect of time duration on steel of 200 hardness or better have yielded negative results. There was never any measurable effect of time."

This is quite surprising to me as it appears to contradict a recent paper reporting a long series of impact tests, I believe by Dr. Nadai, of Westinghouse. These tests showed a sharp

Hipersil Cores for Communications



Designed for a variety of applications in the communications field, a new line of Type C Hipersil cores has been announced by the Westinghouse Electric & Mfg. Co. The cores are available in a wide range of sizes.

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increase of resistance to necking down and rupture of a tension test piece when the load was suddenly applied, a special high-speed flywheel hammer being used in these tests.

Mr. Hagenbook's quick and practical method of determining impact stresses by actual test is of such importance that it should be established in the confidence of engineers generally by a detailed report of the time duration tests he mentions, and an unravelling of the apparent inconsistency with the test results reported by Dr. Nadai. —ROBERT E. BRUCKNER

To the Editor:

Although I am not in a position to prove the absence of time effect with the kind of precision a scientist would like, I have every confidence that its accuracy under impact conditions is fully within the limits of the requirement of the designer in determining the strength of parts of a machine. My reasons for this are as follow:

First, we have used it in connection with a pre-loaded dynamometer and found the values to compare closely when measuring impact of drawbar pull. By this method a dynamometer is pre-loaded as the impact is repeated until the movement of the indicator is a small predetermined amount. This eliminates most of the element of energy absorbtion and over-travel.

Second, I have made tests on a Brinell machine to determine the effect of time. Pieces of flat steel of about 200 Brinell were tested. Impressions were made which lasted 10 min., 5 min., 2 min., ½ min., and 1 sec., or as quickly as the load could be released after coming up to 3,000 kg. On the first run we actually found that the 1-sec. tests averaged higher than the rest, but that there was no measurable difference in the other times. We concluded that we had given the 1-sec. tests an extra load. In our anxiety to make as short a test as possible, we had built up the pressure rapidly and allowed a small overtravel as the weights were picked up. Subsequent tests with more care did not show this increase. No doubt there is an increase in deformation with time, but the kind of accuracy with which Brinell readings are ordinarily made failed to detect it.

Now, my third reason for believing in this method is a priori. The load-sustaining ability of a Brinell impression increases with the square of the diameter and, therefore, the load and the resistance approach each other very sharply. This is not true of a necking sample. Thus, with the ball, any tendency to settle or creep is checked rapidly by the increased resistance of the impression.

Tests run with these ball sets gave us the first data on the loads to expect under conditions of impact, and designs based on them have proven very satisfactory. Whereas a scientist might not consider these reasons and tests adequate, as a designer I have been positively delighted to get figures on impact loads that give such good assurance of being close to the answer. —L. D. HAGENBOOK

WE WELCOME IDEAS FROM OUR READERS

To the Editor:

We respectfully submit for your consideration a suggestion which we believe will considerably improve the usefulness of your magazine. That is to print on the bottom of each page the designation, "Product Engineering," together with the month and year. Our reason for suggesting this is that in many large organizations, such as ours, which have photostat facilities, it is easier to photostat a page of data than it is to make copies on the typewriter or in longhand. Furthermore, the magazine is circulated in different departments and interested departments can photostat a page for their files and pass the magazine along. This practice would be very helpful also if the magazine is used as court evidence. Very often it is possible to photostat a page or so, which is acceptable to the court and does not burden the court record with the mass of the entire publication.

—R. L. PARSELL
Winchester Repeating Arms Co.

EDITOR'S NOTE—Readers will notice that Mr. Parsell's suggestion is being put into practice with this issue. We wish to thank Mr. Parsell for his idea and point out that PRODUCT ENGINEERING always welcomes suggestions from readers.

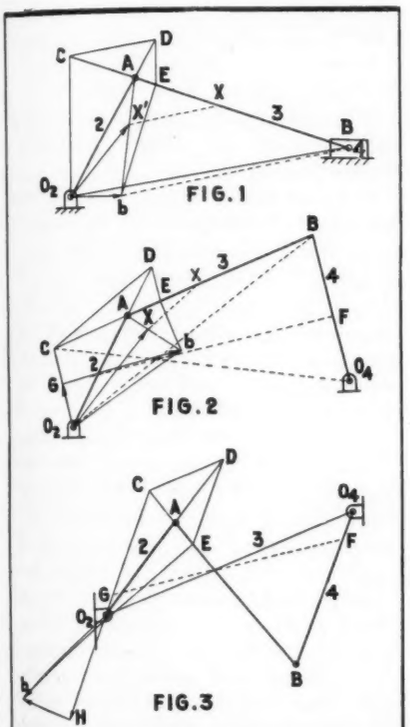
ACCELERATION CONSTRUCTION FOR SLIDER-CRANK AND FOUR-BAR LINKAGES

To the Editor:

When accelerations for several positions of the slider-crank or the four-bar linkage are to be found, it is often possible to simplify the computations by the use of the Ritterhaus construction.

The Ritterhaus acceleration diagram shown in Fig. 1, which is described in many textbooks dealing with mechanisms and kinematics, as

originally derived applied to the slider-crank in which the crank rotated at constant speed. The diagram is constructed as follows: Draw O_2C perpendicular to the direction of motion of B, intersecting the connecting rod (or its extension) at C; draw CD parallel to O_2B, intersecting the crank (or its extension) at D; draw DE parallel to O_2C; draw Eb perpendicular to the connecting rod; draw O_2b parallel to the direction of motion of B. Then O_2A represents the velocity of A and O_2C the velocity of B, both vectors being rotated through 90 deg. from their true directions. Also O_2A represents the acceleration of A, AE the normal acceleration of B with respect to A, Eb the tangential acceleration of B with respect to A, and O_2b the acceleration of B. The acceleration of any point X on the connecting rod can be found by drawing XX' parallel to Bb and then drawing O_2X'. The vectors here are rotated through 180 deg. from their true directions.



Before numerical values can be obtained, suitable scales must be chosen as follows. Let

K_s = space scale
Then 1 in. = K_s ft.

K_v = velocity scale.
Then 1 in. = K_v ft. per sec.

K_a = acceleration scale.
Then 1 in. = K_a ft. per sec. per sec.

The relation between the scales is

$$K_a = K_v^2/K_s \qquad (1)$$

Also the velocity scale must be chosen so that the distance O_2A on the drawing does actually represent the velocity of A. For example, the mechanism shown has a crank 6 in. long and turns 900 r.p.m. If the drawing of the mechanism is half size, O_2A will equal 3 inches. The linear velocity of A is

$$V_a = R\omega = \frac{6 \times 900 \times 2\pi}{12 \times 60} = 47.2 \text{ ft. per sec.}$$

and

$$K_v = 47.2/3 = 15.7$$

Since the drawing is half size, one inch represents two inches or 1/6 ft., therefore

$$K_s = 1/6$$

Then from Equation (1)

$$K_a = \frac{15.7^2}{1/6} = 1{,}480$$

The Ritterhaus diagram can be extended to the open four-bar mechanism in which the crank turns at constant speed by use of the construction in Fig. 2. Procedure is identical with that of the slider-crank except for the location of point b. Lay off BF equal to O_2C, draw BO_2 and CO_4, draw FG through the intersection of these lines, and draw Gb parallel to the motion of B to intersect Eb. Then O_2G is the normal acceleration of B and Gb the tangential. The acceleration of X is found as in the Ritterhaus diagram.

In the crossed four-bar linkage, Fig. 3, the normal acceleration of B is found by drawing O_2O_4 and BC, then drawing FG through the intersection of these lines. CG is the proper length for the vector but it must be laid off in its proper position. Draw O_2H equal to CG and complete the polygon by drawing Hb to intersect Eb.

—C. L. Brown
Purdue University

SHORTCUTS IN MAKING PRODUCTION ILLUSTRATIONS

To the Editor:

Besides the regular freehand sketching of production drawings there are numerous methods of projecting the drawing from blue prints, all of which take considerable time, exceptional skill or both. For faster work which requires little skill in sketching there are the printed perspective and isometric papers which

CARD FILE RECORDS REASONS FOR CHANGES ON DRAWINGS

To the Editor:

Apropos of the article, "Design Practices in Use of Title Blocks," in May, 1943, Product Engineering, pp. 284-287, we have found that merely recording a brief statement concerning a revision on a drawing was insufficient record. Occasionally, after a lapse of time the reason for making a revision was rather vague. So we devised a card file record which gives the history of the revision. A change letter is placed in the usual revision block on the drawing and reference is made to the next successive change card number. The revision block is also initialed and dated and the last shop order number inserted. The accompanying change card shows how a clear history can be made of any change and how it can preclude any possibility of disputes at some later date.

—G. Stevenson
Chief Design Engineer
F. J. Stokes Machine Co.

Change No. ..... Mach. No. .....

Dwgs. Altered .....

Authorized by ..... Memo Date ..... Altered by ..... Date .....

Prints	In Record Set	To Shop	To Jig Maker	To Patt. Shop	B/M Changed
Date					

Reason for Change .....

have long been used to replace the artist or the time-consuming projection methods. Where time and costs are not considered important elements any of these methods or a combination of them serves quite well, but where time and cost as well as the ability to obtain the skilled personnel to make production illustrations enters the picture we must look for an easier and quicker method.

In this office, where we make production illustrations on a job basis for plants which do not have sufficient work to keep one skilled worker busy, we have to invent methods which require little skill and time. The most successful method we have discovered so far is the use of polar co-ordinate paper along with perspective paper and tracing paper. We have made ten photographs of polar co-ordinate paper with the angle of the lens at 10 deg. to 80 deg. to the surface of the paper. These photographs give us a circle at any angle and size. Since the circle is the hardest part of any illustration to make, these photographs cut our time about in half.

The procedure is to rough the sketches out on the regular perspective paper with no attempt to draw in the circles, then with the aid of a light table the circles are traced in from the photographs of the polar co-ordinate paper.

Where the object to be drawn consists of many circles we draw a center line on a sheet of tracing paper, select the required circle as to size and angle, trace these circles from the photographs on the tracing paper and then connect the circles. It is surprising what little time is consumed in running the drawn centerline along the centerline on the photograph and tracing in the required circles. Using this centerline method we have made an outline drawing of an airbrush in 20 min. —E. S. PERRINE

Do You Know That—

THE AMOUNT OF STEEL USED in the manufacture of bottle caps is about equivalent to the amount of steel used in the manufacture of automobile bodies in a normal year. (26)

A SINGLE LAYER OF OXYGEN ATOMS on a sliver of steel the size of a safety razor blade weighs 0.00000002 oz., or about one hundredth as much as a speck of pepper. (27)

SHRINKAGE OF WOOD across the grain is about 40 times that with the grain for the same change in moisture content. (28)

Activities Among Technical Societies

PRESSED METAL INSTITUTE PROMOTES STAMPINGS

Because stampings have played so large a part in the production of war materials, representatives of firms which are familiar with this fabricating process and manufacturers of metal-pressing machinery have organized the Pressed Metal Institute. The principal purposes of the Institute, according to the by-laws, are:

"(a) To promote the increased use of metal stampings, both now and in the postwar period, and to perform such additional cooperative and coordinating services as may be required for the general development and improvement of the industry.

"(b) To inform the public and the various governmental war agencies of the great saving in man hours, materials and costs which is possible through the use of stampings.

"(c) To establish a research and statistical staff, employed by the Institute, for the development of new and extended uses of metal stampings; and to collect, compile and disseminate statistics and information beneficial to the members of the Institute."

George E. Whitlock, president of Mullins Manufacturing Corp., Warren, Ohio, is president of the Institute. Stephen J. Menzel, of Motors Metal Manufacturing Co., Detroit, Mich., is vice-president and H. L. Moody of Stevenson, Jordan and Harrison, New York, N. Y., is secretary-treasurer and managing director. Overall management of the Institute is in the hands of the following Board of Trustees, which also includes the president and vice-president:

Frank E. Graper, Acklin Stamping Co., Toledo, Ohio; W. W. Galbreath, Alliance Porcelain Products Co., Alliance, Ohio; J. H. Robins, American Pulley Co., Philadelphia, Pa.; G. F. Ahlbrandt, American Rolling Mill Co., Middletown, Ohio; William H. Miller, Bossert Co., Utica, N. Y.; W. E. Porter, A. S. Campbell Co., East Boston, Mass.; R. W. Glasner, Clearing Machine Corp., Chicago, Ill.; G. H. Roberts, Detroit Stamping Co., Detroit, Mich.; William J. Meinal and W. C. DeMaris, Heintz Mfg. Co., Philadelphia, Pa.; Roy C. Ingersoll, Ingersoll Steel & Disc Div., Borg-Warner Corp., Chicago, Ill.; I. R. Morris, National Formetal Co., Cleveland, Ohio; and K. T. Norris, Norris Stamping & Mfg. Co., Los Angeles, Calif.

Headquarters of the Institute are at 19 W. 44th St., New York, N. Y. A Washington office has been established in Room 227, 1346 F St., N.W., Washington, D. C.

A recent report from the office of the Chief of Ordnance, U. S. Army, showed that the ordnance conversion program is saving large quantities of aluminum, copper, steel, nickel, chromium, tin, molybdenum and other materials. A good portion of the credit for these savings is given to pressed-metal technique.

Commenting on this report Mr. Whitlock said, "These results are encouraging, but leaders in the industry are convinced that only by united effort, exchange of data and pooling of experience can maximum results be obtained and, therefore, the Pressed Metal Institute was organized. It is believed that through this association, the industry will accomplish much more than individual concerns working alone could possibly achieve, and that opinion is shared, I believe, by government departments. The Institute has very definite plans for broadening the scope of war usefulness and has already developed a constructive, well-organized approach to postwar manufacturing problems.

Meetings

American Society of Mechanical Engineers—Joint meeting with The Engineering Institute of Canada. Sept. 30-Oct. 1. Toronto, Ont.

American Society of Mechanical Engineers—Joint meeting of the Fuels Division with the American Institute of Mining Engineers Coal Division. Oct. 28-29, Pittsburgh, Pa.

American Society of Mechanical Engineers—Annual meeting. Nov. 29-Dec. 3. New York, N. Y.

Management
—Heart of America's Industrial Progress

In Peace and War, Management Men and Methods Steer Production on a Steady Upward Course

WHEN the Allied armada of 2,000 ships, protected by a vast umbrella of planes, struck the coast of Sicily, Axis leaders once more had reason to wonder how "that decadent, pleasure-loving America" had swung from the manufacture of automobiles, refrigerators and costume jewelry to equipments of war, and had out-produced such mighty plants as the Krupp, the Fiat and the Skoda works — and had done it so quickly.

America at war is in the lead just as it has led a world at peace. Super-performing planes are taking to the air at the present rate of nearly 100,000 per year. Ships, to carry the war to our enemies, slide down the ways at the rate of two a day. Tanks, trucks, guns, ammunition are pouring out of our "peace" plants in far greater volume than the entire Axis effort can possibly equal. War expenditures in 1943 alone will reach the staggering figure of approximately $83,000,000,000 — an amount equal to our entire national income for 1929. Added to this is the rock-bottom output of essential civilian goods — a very considerable item.

This unprecedented production is taking place while some 9,000,000 men and women, those physically best equipped, have been called to the armed forces. Many of them were taken from industry, and their loss could be repaired only by more efficient equipment and more effective methods.

Rigorous training programs had to be superimposed upon many other abnormal problems facing industry in its high-speed conversion from stoves to boats; from printing machines to guns; from automobiles to airplane engines; from fishing tackle to bomb sights.

This phenomenal task was further complicated by the need for rapid expansion. A modest machine tool industry had to be expanded to handle a volume many times its normal capacity. Steel production had to be increased by 20%, and that of aluminum and magnesium multiplied over and over. From almost nil, the demand for high octane gasoline soared to unbelievable quantities. The creation of synthetic rubber and electronic industries was necessary almost overnight.

Who deserves credit for these accomplishments? All industry! The engineers, chemists, designers, skilled workers, common laborers. But over and above all it belongs to *management*.

In industry it is mandatory to have a directive force to co-ordinate the efforts of men in the use of materials and the application of power toward the production of goods and services. The application of this directive force is the function of management, and only because we had today's kind of management were we able to transform ourselves, almost overnight, from a peace-loving nation to the world's greatest producer of implements of war. As a nation, we had been preparing for a long time to play our part in world affairs. This preparation, certainly not planned for today's objectives but none the less effective, began some four decades ago.

With the advent of the twentieth century, the character of industry in the United States, and, therefore, the character of American living, began to change. Scientific management was born. Frederick W. Taylor brought into focus and showed how to use effectively those processes and procedures upon which our present-day mass production is based. He was followed by Harrington Emerson, who made the industrial world acquainted with efficiency in manufacture and the remarkable progress to be gained therefrom in the field of production, with its consequent price reductions and wider distribution of industry's products. There followed, in industry, an alert management, a capable management, a management with vision. Without it, the work of Taylor and Emerson would have gone for naught.

It is because of this early work of management — and the extraordinary developments it produced — that the country as a whole, and particularly those employed in industry, were not over-awed by the seemingly impossible job of quick conversion to all-out war production. But let us look back four decades and examine some of those preparatory accomplishments which have proven so vital to the progress and welfare of the nation.

From 1900 to 1939 (the last pre-war year), total employment of all kinds increased 52 per cent; in the manufacturing industries alone the increase was 84 per cent. *The nation became definitely industrial.*

In 1900 the average wage earner was able to spend only 20.2 per cent of his income for things other than necessities; in 1930 his buying power for non-essentials had increased to 34.8 per cent. *The average man acquired confidence in what industry could do.*

In 1900 the average work week was 56 hours; in 1930 it was 48 hours. *The burden of production was being transferred from man to machine.*

In 1939 the United States possessed 30 per cent of the world's railroads, 72 per cent of its automobiles, 49 per cent of its telephones. *The nation's production equipment had grown to formidable proportions.*

In 1939 nearly half of the families in the United States owned their own homes, 64 million individuals carried life insurance policies and 45 million had savings accounts. National income had increased 300 per cent from 1900 and during the same period the proportion of national income paid out in salaries and wages increased from 58 to 70 per cent. And in less than this period (1914–1939) the purchasing power of the wage rate increased by 60 per cent. *There had been evolved the kind of living for which men will work — and fight.*

Since 1900, factories increased their output of goods from $11,000,000,000 to $60,000,000,000 in 1939. This increase of nearly 450 per cent was accomplished while the country's population rose only 60 per cent. In this same span of years, technological developments and improvements in methods had

increased the value added by manufacture per wage earner by 200 per cent, and the horsepower per factory worker had been multiplied by 2½. *The nation's production plant was ready to assume its gigantic wartime job.*

During this period of industrial and national evolution, management itself had changed. Prior to the advent of scientific management, our goods and services were the product of several kinds of directive activities, varying from the strictly paternalistic to the ruthless. There was little conception of the responsibility that industry now broadly acknowledges — the responsibility of trusteeship in the interest of stockholders, employees and the public — specifically; in the interest of our national economy — generally. Acceptance of this stewardship is acceptance, also, of the belief that, in the long run, no industry, and no unit of industry, that does not serve society can live.

Have the actions of management caused the times to change? Or has an alert management been successful only because it has changed with the times? Certainly, the industrial concern of 1900 would not thrive under the conditions of today. Just as certainly the new things that industry has in store for a waiting postwar world will have a far-reaching effect upon the times.

Management today seldom owns the factory or the business it manages. It is hired to perform the coordinating, directive functions. It is free to change — of itself, or with the times. Management therefore exercises its power through leadership in executing ideas . . . not through ownership.

This is the fourteenth of a series of editorials appearing monthly in all McGraw-Hill publications, reaching more than one and one-half million readers. They are dedicated to the purpose of telling the part that each industry is playing in the war effort and of informing the public on the magnificent war-production accomplishments of America's industries.

Good management can be sustained only in an environment sympathetic to its aims. It has an undeniable obligation to society, because it must be a compatible part of the social structure or be rejected by that structure as a whole.

An environment sympathetic to its aims means, also, that industry, in the very serious reconstruction period ahead, will not be at full effectiveness if it is subjected to attacks by government no matter what the underlying reasons may be — over-zealous devotion to a cause, lack of understanding or just plain politics. It was to industry — to industrial management — that the government turned when our existence as a free nation was threatened; it is to industrial management that government must turn in order to win the peace.

This statement is made in the sincere conviction that what has made America strong is industry's ability to produce consistently more and more goods and services for more and more people. It is only by actually creating them that we built up our stockpiles of the necessities of life. And it is only by creating them that we can have more of those things that make life worth while. These become available to more people as industry succeeds in getting greater output of goods and services for a given input of human energy, materials and power.

And what of the physical jobs ahead? In this country alone, there will be an immense demand upon industry to supply the things people have been unable to purchase during the war. Today the nation is wearing out not only its automobiles, refrigerators, vacuum cleaners and radios, but its very houses, its roads, railroads, and airline equipment. It is saving its money while whetting its appetite. Truly, the calls the American people will make upon industry in the postwar period will be many and insistent.

This demand can be viewed in another light. Economists say there will be 56,000,000 persons seeking gainful employment after the war. The Committee for Economic Development has estimated that $140,000,000,000 worth of goods and services will be required each year for those people. Compare that with our actual output of $97,000,000,000 worth of goods and services in 1940 when gainful employment was 46,000,000.

These future jobs will be done if industry's management is not too much hampered by government management. Management in industry performs its function in the field of *doing* things. Management in government performs its function in the field of *regulating* things. The best cooperation of the two kinds of management will be necessary in the postwar period. Certainly, too much of the regulatory kind will interfere seriously with the kind that does things.

Industrial management must improve, too. If it is too selfish, if it does not recognize definitely the trusteeship inherent in its job, if it does not understand and live up to its social responsibilities, then it will be risking all for which we are fighting. The following suggestions are made to indicate the direction that management's self-improvement can take.

Evolution in management has been too slow in some respects. Management in industry has been too prone to see the advantages in technological development while being blind to its evils. Looking at industry and social progress as a whole, there can be no doubt as to the value of technological improvement. It creates jobs. It elevates the standard of living. But that economic fact is of no satisfaction to the individual who loses his job because a new machine or a new method required one less man. By and large, this is an evil that management can do something about.

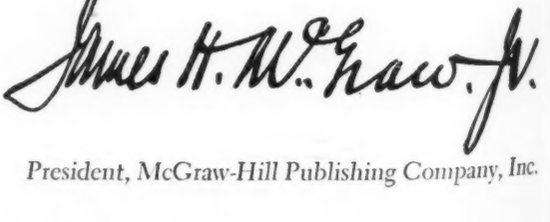
Management has been too careless of its opportunities with regard to labor. On that account the pendulum of social readjustment has swung too far. Labor has been given extensive privilege without corresponding responsibility.

Industrial management has been too slow to abandon its policy of letting the buyer beware. As a result of this, industry today is over-regulated.

Management has been too slow in recognizing its responsibility to promote the economic philosophy that a society cannot have for consumption what it does not produce. A companion educational item too long neglected is management's obligation in the field of public relations.

In these years since 1900, industrial management has been growing. Perhaps many of its experiences have been but growing pains. Management has learned, among other things, the absolutely vital need for capital at the right time and in the right amount. It has learned to use some of its earnings as "seed-money" in the introduction of new products and the use of new processes. It has learned to invest more and more in research. It has learned of the interdependence of industry and agriculture. And it has learned much about the eternal triangle of industry, labor and government.

With such a history and such experiences behind it, I have every faith that management is going ahead to even more glorious accomplishments in the winning of the war, and I believe that its peacetime accomplishments to come are beyond the prediction of any of us — even management itself.



President, McGraw-Hill Publishing Company, Inc.

Books and Bulletins

Applied Electronics

By members of the staff of the Department of Electrical Engineering, Massachusetts Institute of Technology. 772 pages, 6x9 in. Blue clothboard covers. Published by John Wiley & Sons, Inc., 440 Fourth Ave., New York, N. Y. Price $6.50.

Although this book is intended to serve as a basic course in electronics to present data on the functional methods by which electronics serve engineering, considerable additional material is included for the student. For that reason, upon casual glance, the mathematical equations may frighten the beginner. The subject matter is very broad. It includes chapters covering the fundamental data on electron emission and high-vacuum and gas tubes as well as special applications—amplification, rectification, oscillation and detection. Each of the divisions is complete and informative. The engineer will find this book a thorough introduction to electronics, and a very useful reference volume.

Table of Arc Tan X

Published by National Bureau of Standards, U. S. Department of Commerce, Washington, D. C., 173 pages, 8⅛x10½ in. Tan clothboard covers. Price $2.

This volume, designated MT 16, is the first contribution to what it is hoped will be a complete set of tables of the inverse trigonometric and hyperbolic functions. The function

$$\text{Arc Tan } x = \int_0^x \frac{du}{1+u^2}$$

is tabulated in this volume to twelve decimal places.

Refrigerating Data Book

Published by American Society of Refrigerating Engineers, 50 West 40th St., New York, N. Y., 678 pages, 6¼x9⅞ in. Brown leatherette covers. Price $4.

Compiled with the cooperation of the society's members, this volume covers refrigerating cycles, fundamental data, industrial systems, domestic-commercial systems and air-conditioning systems. It is virtually a revision of the 1939 edition, bringing the material up-to-date and presenting what new fundamental data has been developed. The book belongs in the library of any engineer who deals in any way with refrigeration or air-conditioning machinery.

Heat-Treatment of Metals

J. Winning—100 *pages, 5½x8½ in. Red clothboard covers. Published by Chemical Publishing Co., Brooklyn, N. Y. Price* $1.50.

Written for engineers and others who have not specialized in metallurgy but who daily make contact with heat-treatment and its problems, this book summarizes modern heat treating methods along with the principles on which they are founded. The author introduces the subject with general principles, then describes various types of furnaces and equipment, including those with controlled atmospheres, casehardening processes, and flame and induction hardening processes. He then discusses special types of carbon and alloy steels, stainless and non-ferrous alloys. The final chapter tells how to draw up a program of heat-treatment. The book is written with a British viewpoint, and contains neither table of contents nor index.

Aircraft Hydraulics

Harold W. Adams—159 *pages, 6x9 in. 94 illustrations. Blue clothboard covers. Published by McGraw-Hill Book Co., 330 West 42nd St., New York, N. Y. Price* $1.75.

Many parts of an airplane, including landing gear and wing flaps, are motivated by power supplied through hydraulic transmission circuits. Material is presented in this book to familiarize the reader with the various parts of such circuits, and this also serves to direct attention to the importance of the chapter on the "Flow of Fluids," which clarifies many important hydraulic principles.

The book is divided into four parts, the first covering description of basic systems and the science of fluid flow. Parts II and III are on design—the former on design requirements for power systems and sub-systems, and design procedure; the latter on design of basic and special-purpose units, and hydraulic-unit design procedure. The fourth section covers drafting of aircraft hydraulic systems, manufacture of aircraft hydraulic units, installation of aircraft hydraulic systems, testing units and the maintenance of aircraft hydraulic systems.

The material is well written and clearly illustrated by simple sketches.

Differential Equations

H. W. Reddick—245 *pages, 5½x8½ in. Clothboard covers. Published by John Wiley & Sons, Inc., 440 Fourth Ave., New York, N. Y. Price* $2.50.

This text book, as the title implies, deals with methods of solving ordinary differential equations; it does not include any treatment of partial differential equations. The volume is designed to teach students, who have an understanding of the fundamental concepts of differential and integral calculus, how to apply that theory to the process of determining the mathematical relations inherent in engineering problems, as well as their physical and geometric applications. More than 600 problems are included as exercises in the use of the methods and operations described. To help the student check his work, answers are included for all the problems.

• • •

Spur Gearing

W. M. Owen—64 *pages, 6x9 in., illustrated. Published by McKnight & McKnight, Bloomington, Ill. Price 72 cents.*

Fundamentals for laying out gears are presented in concise form in this booklet that is the basis of the apprentice training course offered by the Caterpillar Tractor Co. It should provide quick help to anyone confronted with elementary gear problems.

Extruded Plastic Tubing And Shapes

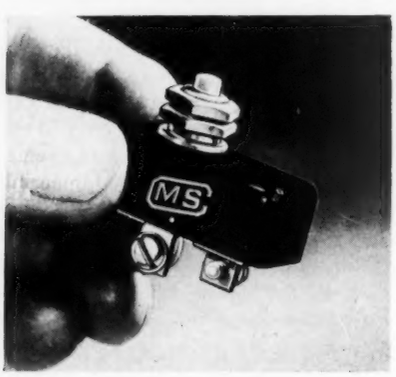
Published by Society of the Plastics Industry, 295 Madison Ave., New York, N. Y. 16 pages, 9x12 in., illustrated. Price $1.

The Thermoplastic Division of the S.P.I. Technical Committee undertook the compilation of the information in this catalog at the request of the Naval Aircraft Factory so that there would be a ready source of data on extruded plastic tubing, fittings and shapes. Extrusion materials and product trade names are listed as well as companies which extrude thermoplastics and data on available tubing.

NEW MATERIALS AND PARTS

Small Precision Switch

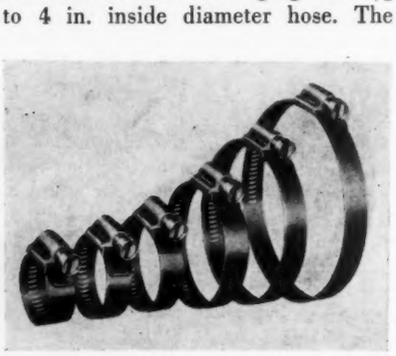
No bigger than the end of a man's index finger, the Peanut Micro Switch is the tiniest in a line of small precision switches. The unit was designed for postwar use, but war requirements have necessitated putting it in full



production. The switch is available with or without a case. The electrical rating is high, contact gaps up to 0.085 in. can be varied in manufacture and commercially pure silver contacts are used. The contacts are formed with a knurled surface to provide high unit contact pressure for low voltage application. Micro Switch Corp., Freeport, Ill.

Hose Clamps

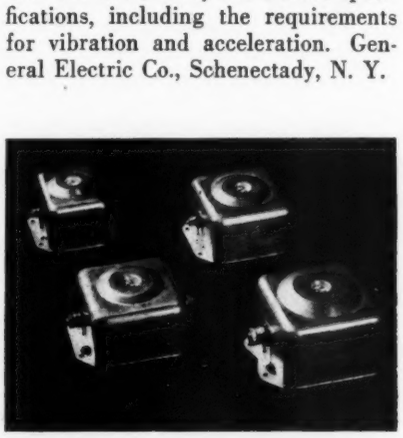
Consisting of a $\frac{3}{8}$-in. tempered-steel band punched with holes corresponding to the teeth of a worm gear, a new line of Aero-Seal hose clamps is available in 14 sizes ranging from $\frac{3}{4}$ to 4 in. inside diameter hose. The



holes mesh with a worm in the housing welded to the fixed end of the band. The worm is turned by a screwdriver, and the screw head on the worm is fitted with a safety cup which prevents the screwdriver from slipping. The worm-and-gear action provides a self-locking feature which withstands severe vibration as long as the band is kept under tension. Aircraft Standard Parts Co., 1711 19th Ave., Rockford, Ill.

Radio-Noise Filters

Designed to help provide the high-fidelity radio reception necessary in aerial warfare is a new line of radio-noise filters. They are compact, lightweight, can be mounted in any position and will operate over a temperature range of ± 50 deg. C. Available in ratings of 20, 50, 100 and 200 amp., d.c., at 50 volts, the new filters comply with the U. S. Army Air Forces specifications, including the requirements for vibration and acceleration. General Electric Co., Schenectady, N. Y.

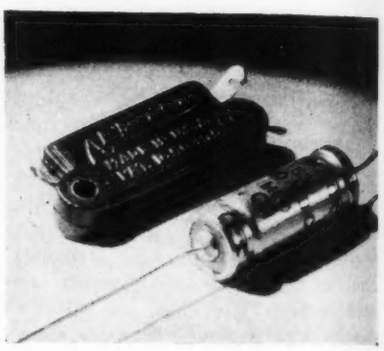


White Tracing Cloth Resists Moisture

One of the outstanding features of Whitex, an improved white pencil tracing cloth, is that it resists moisture on both sides. This guards against spots from perspiration or moist hands. The fine-tooth surface helps to make pencil lines jet black. The cloth has a glass-like transparency. Frederick Post Co., Box 803, Chicago, Ill.

Oil-Filled Capacitor

For use where space and weight are important factors, the Type 38 metal case, oil-impregnated, oil-filled, small capacitors can be used in place of mica capacitors. They meet standard



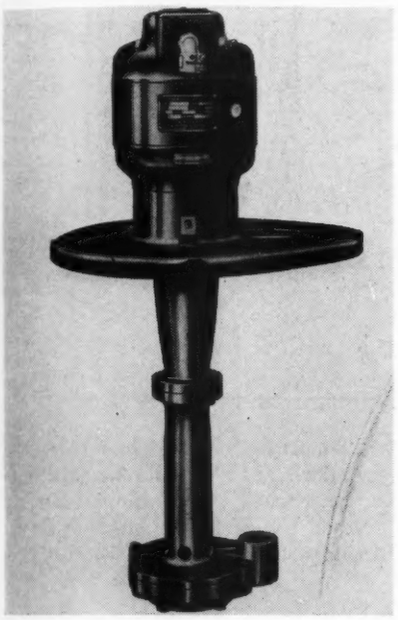
specifications for paper dielectric capacitors used as mica alternates. Units are available with both terminals insulated or with one terminal grounded to the case. Pigtail terminals are provided. Measurements are 1 and $1\frac{3}{16}$ in. long, and $\frac{13}{16}$ and $1\frac{1}{16}$ in. in diameter. Castor or mineral oil is used as the impregnant and filler. Ratings are 300 to 800 d.c. working voltage and capacitances range from 0.001 to 0.01 microfarads. Aerovox Corp., New Bedford, Mass.

Vitreous-Enamel Coating

Resistance to acid, mild alkalies, rust, corrosion, heat, impact and abrasion is a feature of a vitreous-enamel coating, called Silco, which may be buffed to an egg-shell gloss. The coating is sprayed on, dried at 200 deg. F. and baked at 350 deg F. in convection type ovens or by infra-red lamps. The coating withstands heat up to 1,000 deg F. and is not affected by a 200-hour salt spray test. Although the coating is inflexible, it will bend 30 deg. without breaking. Thickness is 0.0001 to 0.0002 in. Available colors are black, army-drab and navy-gray. Mitchell-Bradford Chemical Co., 2446 Main St., Bridgeport, Conn.

Coolant Pump For Deep Immersion

Designed for deep immersion is the Gusher vertical coolant pump, identified as Model TL. It will handle soluble coolants containing abrasive material without injuring the mechanism. An integral mounting flange is usually bolted to the reservoir cover or bedplate. The shaft, which rotates on two ball bearings, is of one piece construction and ground accurately to



insure balance. It extends from the motor to the impeller. The pump is available in two lengths from the mounting flange to the bottom of the pump. One is 23⅝ in. and the other is 19⅝ in. The unit is equipped with a ½-hp. totally inclosed motor for continuous duty, or a ¾-hp. motor for extra heavy duty. Ruthman Machinery Co., 1810 Reading Road, Cincinnati, Ohio.

Aluminum Coating Can Be Plated

With the two-step Ebonol "A" process for coating aluminum, it is possible to use the coating produced as a base for electroplating. The normal procedure consists of cleaning, applying an adherent film of zinc and then blackening the zinc film. This requires two solutions, one for the zinc coating and one for blackening this coating. The coatings produced are hard, metallic oxides which have good adhesion, but will not withstand severe deformation. The process is not meant to be a substitute for anodizing, and does not protect aluminum to the degree that dyed anodic coatings do. It is for blackening aluminum parts shielded from severe weather in use. Thickness of the coating varies from 0.00003 to 0.00008 in. Dimensional changes are of the order of 0.00003 in. When the zinc film is used as a base for electroplating, the work should be cadmium plated if the parts are to be soldered. For general plating, it is suggested that copper be deposited from a cyanide solution. This copper coating can then be plated with nickel, chromium, silver, or other metals. Dept. PE, Enthone Co., 442 Elm St., New Haven, Conn.

Air Control Valve

Accurate split-second timing of piston movement is possible with a rapid-acting value for the control of air. Beginning with full capacity flow in both directions, the flow in one direc-

tion can be controlled over a wide range to a closed position. Numerous speeds can be selected with a vernier-like adjustment mechanism. A specially designed stem and floating bevel seat poppet maintain positive control at any selected speed. Ross Operating Valve Co., 6495 Epworth Blvd., Detroit, Mich.

Safety Control For A.C. Arc Welders

When an arc from a transformer-type a.c. arc welder is broken, the transformer can be automatically disconnected with the Class 8992 safety control panel. Conversely, the transformer is automatically reconnected as soon as the operator touches the electrode to the work. Thus, hazards created by high open circuit voltages

are eliminated. As an economy angle, the welding transformer primary circuit is connected to the power line only while the arc is held, allowing savings in power. External connections are simple and internal connections of the welder need not be disturbed. Industrial Controller Div., Square D Co., Milwaukee, Wis.

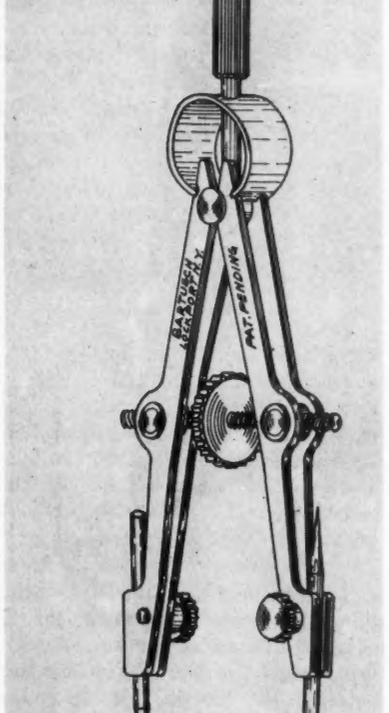
D. C. Vertical Motors

Designed for low-thrust, solid-shaft application on pumps, machine tools and marine underdeck auxiliaries is a line of direct-current vertical motors ranging from 40 to 200 hp. at 1,750 r.p.m., and equivalent ratings at other speeds. They are furnished for both constant and adjustable speeds. Motors are of drip-proof construction. Convenient fittings on the upper and lower bearings simplify lubrication and provision is made for the escape of excessive grease. A special bearing housing prevents grease from entering the motors. The cast iron conduit box can be arranged to bring the lead in at the top, bottom or either

side. Two hand-hole covers permit quick inspection of the commutator and brushes. The ring-type base has an accurately machined rabbet and jig-drilled mounting holes. General Electric Co., Schenectady, N. Y.

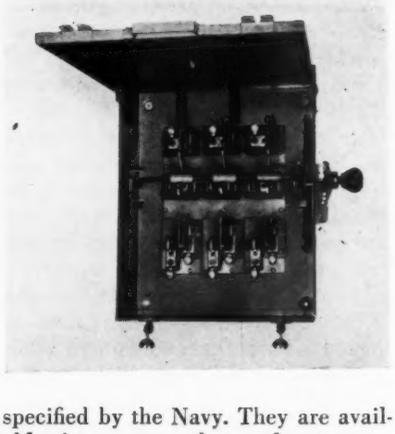
Bow Compass and Dividers

Four-leg construction with deeply shouldered and flanged fulcrum and adjusting wheel nuts, all of which make for rigidity, feature the 3-in. bow compass and dividers for layout work on paper, metal or other material. The center point and pencil lead or metal scriber are clamped in machined V-grooves. The entire assembly is made of Monel metal. Both instruments can be set from 0 to 2⅝-in. radius. All points are of hardened tool steel. The toolmakers dividers have a finer adjustment than the bow compass. A. P. Bartusch, 775 Walnut St., Lockport, N. Y.



Double-Throw Marine Switch

Augmenting the present Type K single-throw marine switch, a new line of double-throw switches is being built to government requirements. These switches are splash-proof and designed to withstand shock tests as specified by the Navy. They are available in two- or three-pole arrangements, ratings from 30 to 100 amp., 250 volts a.c.-d.c., 575 volts a.c., and either fusible or non-fusible types. Switch & Panel Div., Square D Co., 6060 Rivard St., Detroit, Mich.



Thermostatic Bimetal

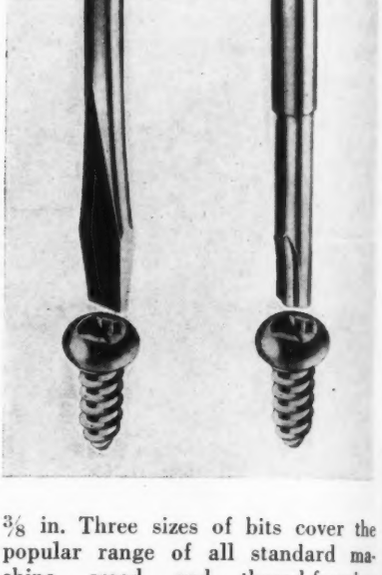
High electrical resistance and thermal deflection rates have been combined in a recently announced thermostatic bimetal, designated No. 6850. Electric resistivity is given as 850 ohms per circular mil foot, or 668 ohms per square mil foot at room temperature. Deflection rate is virtually uniform between 0 and 400 deg. F. and is slightly lower above and below these extremes. Operating characteristics are said to remain constant at temperatures as low as —100 deg. F. W. M. Chace Co., 1607 Beard Ave., Detroit, Mich.

Non-Corrosive Wrapping Paper

Two protective layers in one paper make up a new greaseproof, non-corrosive wrapping paper for the protection of highly finished metal parts. Known as V-26, this product is reported as meeting or surpassing all government specifications for such papers. The inner ply provides a greaseproof barrier for the retention of corrosion preventive used on metal products, while a strong outer ply protects the greaseproof membrane against damage in transit. Both inner and outer laminations consist of neutral kraft and are creped for greater flexibility in wrapping, with a dead limp folding quality. The paper is available either with an outer film of wax that provides a self-sealing surface or uncoated where the self-tack quality is not needed. Sherman Paper Products Corp., Newton Upper Falls, Mass.

Socket Head Screw

Designed for use with either an ordinary screw driver or a special assembly bit, screws with heads like the ones illustrated are known as Clutch Head Screws. The socket arrangement is available for all types of heads and in nominal screw sizes from No. 6 to ⅜ in. Three sizes of bits cover the popular range of all standard machine, wood and thread-forming screws. United Screw and Bolt Corp., Chicago, Ill.

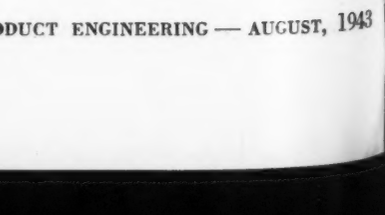


High-Speed Printer

Black and white prints or blueprints can be produced at speeds ranging from 20 to 25 ft. per min. with the Model 157 printer. The unit was perfected as an aid in speeding up reproduction of engineering drawings in war work. High speed is made possible by use of a mercury-vapor quartz lamp that is claimed to be the equivalent of 6 to 8 carbon-arc lamps. Charles Bruning Co., New York, N. Y.

Push-Pull Gages

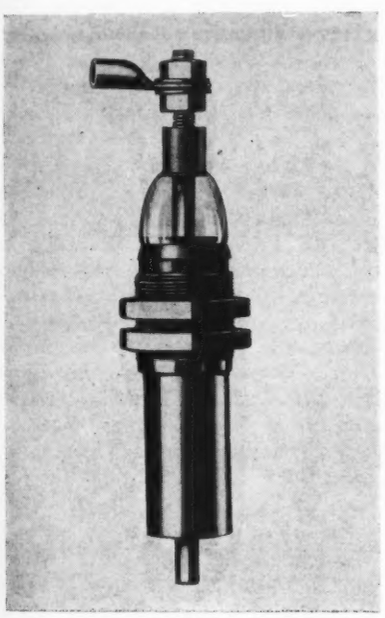
Measurement of tension, pressure, mechanical reaction, breaking strain and other light forces from ½ gram to 100 lb. can be made with the push-pull gage illustrated here. Some of the possible uses are for testing spring characteristics, measuring the pull of



a relay or magneto, checking the pressure required to operate push-pull button switches, adjusting the operation of spring-loaded mechanisms, determining the breaking strength of fibres. Manufactured in standard models, the gages are compact and lightweight. Each gage is individually calibrated, made to precision limits, and accurate within one gradation mark. John Chatillon & Sons, 85 Cliff St., New York, N. Y.

Gas-Tight Terminal

Applicable in places where an insulated terminal is required for equipment in a sealed container is a gas-tight terminal for use on radio coaxial cables. The seal is obtained by fusion of glass to metal. A metal alloy



of suitable coefficient of expansion is used. The unit shown is installed on the end of a 7/8-in. coaxial cable. Other sizes are available. Victor J. Andrew Co., 363 E. 75th St., Chicago, Ill.

Quick-Release Hinge

Instant release and easy removal of a door, table, hood or chute are prinipal features of a hinge designed for quick release. The unit is composed of a bracket housing spring loaded attaching pin, equipped with finger pads to retract the pins. When the pads are forced together the hinged part is free. Present models are available in several bracket designs and lengths from 2 to 6 in. Burklyn Co., 3429 Glendale Blvd., Los Angeles, Calif.

Printer

Designed to meet the requirements of firms whose print production has graduated from the small to the inter-

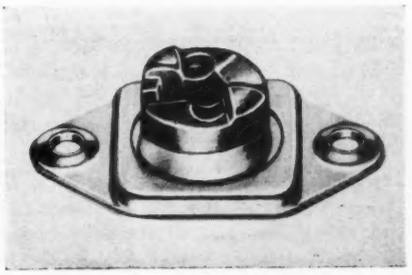
mediate stage, is the 8Q printer. The unit will expose blueprints, direct process prints, and sepia negatives up to 54 in. wide. Speeds range from 6 in. to 32 lineal ft. per min. The printer incorporates a revolving contact, and uses a quartz high-pressure mercury-vapor lamp. Paragon-Revolute Corp., 77 South Ave., Rochester, N. Y.

Corrosion-Resistant Coating

Formulated with new and improved synthetic resins, a surface coating, known as Ucilon, is intended to withstand many corrosive conditions. The coatings are said to be tough, flexible, and resistant to organic and inorganic acids, alkalies, salt, alcohol, gasoline, oils, greases and moisture. Dielectric strength is reported as excellent. The coatings may be applied to wood, metal, concrete and other surfaces by brushing, spraying or dipping. A special formulation is available for food-processing applications. United Chromium, Inc., 51 E. 42nd St., New York, N. Y.

Cowl Fastener Has Floating-Cam Collar

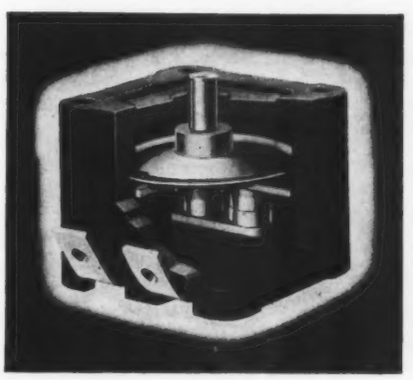
Large spotting tolerances are allowed with the Camloc line of high-speed cowl fasteners which have been provided with floating-cam collars.



Other cam collars include straight, corner, ear and bracket models. Rivet-type cam collars are used for interchangeability with other fasteners and where limited-edge clamps prevent a standard single-hole mounting. They are adaptable to metal, plastics and plywood. All cam collars can be used with both slotted and wing-head assemblies of the same series. Camloc Fastener Corp., 420 Lexington Ave., New York, N. Y.

Sealed Switches

Protection of the contact against dirt, dust, sand and oil are provided in the A-3 and A-5 switches by sealing them in phenol-plastic cases. This protection feature has been incorporated to make the switches more satisfactory for electrical control units on war equipment that may be used



where climatic conditions would cause failure of units that were not sealed. Allied Control Co., 2 East End Ave., New York, N. Y.

Hard-Facing Alloys

Two new hard-facing alloys of cobalt, chromium and tungsten, called Stoody 1 and Stoody 6, are furnished as welding rods for application by the oxy-acetylene process. Stoody 1, the harder of the two alloys, provides high resistance to abrasion, corrosion and heat. It is recommended for such equipment as hard-facing pump sleeves, wood-saw teeth, carbon scrapers, wire guides and expeller parts. Stoody 6 is not quite so hard as Stoody 1, but is more ductile and provides greater impact resistance. It is useful for hard-facing high-pressure, high-temperature valves, gasoline and diesel exhaust valves, various types of dies, shear blades and cams. Both rods are supplied in 1/8, 3/16, 5/16 and 3/8 in. diameters and 14-in. lengths. Stoody Co., Whittier, Calif.

Manufacturers' Publications

Cable—Western Electric Co., 195 Broadway, New York, N. Y. Booklet, 40 pages. Telephone switchboard and lead-covered cables developed by Western Electric engineers in collaboration with Bell Telephone Laboratories and the research laboratories of the American Telephone & Telegraph Co. are described.

Control — Bristol Co., Waterbury, Conn. Bulletin A112, 8 pages. Refinements in the Free-Vane convertible type air-operated controllers are highlighted.

Abrasives — Behr-Manning Corp., Troy, N. Y. Booklet 16 pages. Many applications of coated abrasive cloth and fibre are shown.

Thermocouples—Arklay S. Richards Co., Newton Highlands, Mass. Catalog No. 3, 12 pages. Describes parts, assemblies and accessories of standard industrial thermocouples for all makes of pyrometers.

Wood—Kay Displays, Inc., 9 E. 40th St., New York, N. Y. Booklet, 32 pages. Points out how wood can help solve design and production problems on war equipment and highlights several examples of how the firm has helped war contractors.

Tubing — Summerill Tubing Co., Bridgeport, Pa. Data sheets, 22 pages. Aircraft tubing specifications for both Government and Aeronautical Specifications covering seamless, welded and stainless tubing are brought up-to-date and new data on machining allowances and a heat-treating chart for NE-8630 steel are added.

Power Unit—Hydraulic Machinery, Inc., 13825 Ford Rd., Dearborn, Mich. Catalog, 4 pages. Ten different models of hydraulic power units are shown as typical of what can be done in conjunction with new machines or for changeover of existing equipment to hydraulics.

Welding Alloys—Eutectic Welding Alloys Co., 40 Worth St., New York, N. Y. Chart. Physical properties and procedure information for low-temperature welding alloys are contained.

Filter—General Electric Co., Schenectady, N. Y. Bulletin GEA-4098, 8 pages. Gives electrical and mechanical characteristics, performance and installation data, weights and dimensions for a new radio-noise filter.

Valves—R-S Products Corp., Wayne Junction, Philadelphia, Pa. Bulletin No. 16-B, 4 pages. Contains dimension tables for manually or automatically controlled butterfly valves ranging from 15 to 125 lb. per sq. in. and used for regulating gases or liquids.

Plating and Polishing Equipment—Chas. F. L'Hommedieu & Sons Co., 4521 Ogden Ave., Chicago, Ill. Catalog No. 5, 228 pages. Machinery and related equipment for plating and polishing operations are completely described.

Sheaves—Worthington Pump & Machinery Corp., Harrison, N. J. Bulletin V-1400-B7C, 16 pages. Describes features of Quick-Detachable sheaves and gives detailed dimension and application data.

Manganese Steel—American Manganese Steel Division, American Brake Shoe Co., Chicago Heights, Ill. Bulletin No. 543-G, 48 pages. How manganese steel is helping industry in general to "carry on" in war production is the theme of this brochure.

Electric Brake — Empire Electric Brake Co., S. 14th St., Newark, N. J. Bulletin, 6 pages. Dimensional drawings for and torque delivered by each of three stock sizes of the Magdraulic electric brake are included.

Duplicator — American Photocopy Equipment Co., 2849 N. Clark St., Chicago, Ill. Folder. Describes a machine for making photographic copies up to 18x24 in.

Control — Askania Regulator Co., Chicago, Ill. Bulletin No. 118, 4 pages. Describes and illustrates the hydraulic jet-pipe principle of automatic control.

Joints—Brooks Equipment Co., 90 West St., New York, N. Y. Book, 48 pages. Consolidated hinged joints, which operate at angles from 0 to 90 deg. in any given plane, and Brooks universal joints, which operate at angles from 0 to 360 deg. in any plane, are presented along with data sheets, drawings and descriptions of all equipment necessary for installation.

Vibrating Equipment — Jeffrey Manufacturing Co., Columbus, Ohio. Catalog No. 750, 176 pages. Components of electric vibrating units are described and illustrated.

Motors—Century Electric Co., 1806 Pine St., St. Louis, Mo. Bulletin 344A, 16 pages. Tells how to select the squirrel-cage induction polyphase motor best suited for the application.

Tubing—Titeflex Metal Hose Co., 500 Frelinghuysen Ave., Newark, N. J. Catalog No. 113, 36 pages. Types of flexible metal tubing for conveying gases and liquids, data on fittings and charts covering pressure, radius of bend and other essential information are included.

Rectifiers—McColpin-Christie Corp., 4920 S. Figueroa St., Los Angeles, Calif. Catalog Sheets Nos. 300 and 301, 2 pages each. Advantages of over 50 new models of industrial electrical rectifiers are explained.

Rivet—B. F. Goodrich Co., Akron, Ohio. Manual 2-8970-G, 12 pages. The Rivnut, an internally threaded and counterbored tubular rivet that can be headed blind, is completely described.

Control — Brown Instrument Co., Wayne and Roberts Aves., Philadelphia, Pa. Bulletin No. 87-1, 8 pages. Details of the operating principle of the pattern transmitter and the control instrument of the Time-Pattern controller are described.

Molding — Resinous Products & Chemical Co., Washington Sq., Philadelphia, Pa. Bulletin, 16 pages. Flexible bag molding of curved plywood is discussed.

Reproduction — Paragon-Revolute Corp., 77 South Ave., Rochester, N. Y. Handbook, 40 pages. Describes the various processes and equipment for making blueprints, direct-process prints, sepia prints and reproduced tracings.

Lights—Reliance Devices Co., 510 Sixth Ave., New York, N. Y. Catalog No. 102, 4 pages. Dimension and application data for Swivelier Worklites are given.

Wiring Diagram Symbols

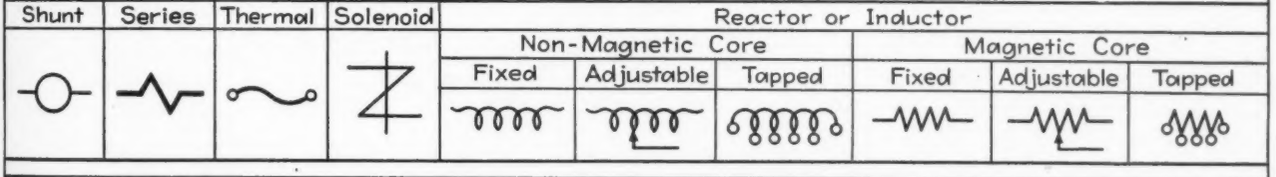
(Recommended by National Machine Tool Builders Association)

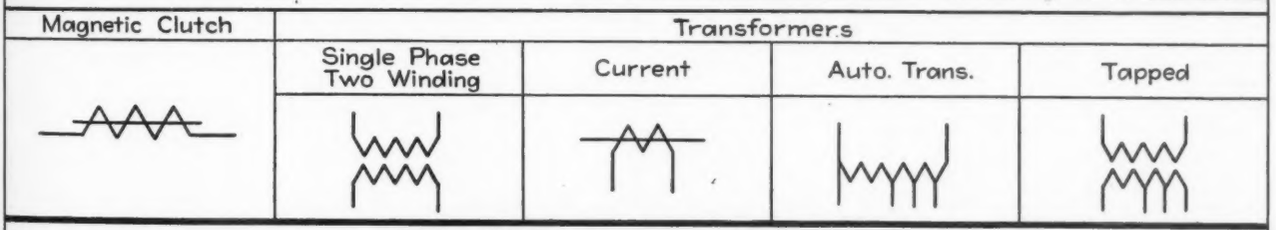
N.E.M.A. Industrial Control Standard Device Markings

The markings given in this box are intended for use on diagrams in connection with symbols to indicate the function or use of the particular device.

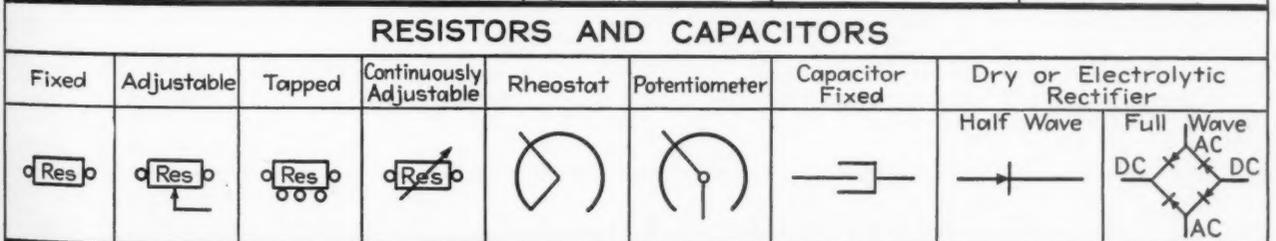
Armature accelation	*A*	Field forcing (increasing on variable voltage)	*CF*	Lowering	*L*
Armature shunt	*AS*	Field protective (field weakened at standstill)	*FP*	Low speed	*LS*
Aux. switch (breaker) normally open	*"a"*	Field reversing	*FR*	Low torque	*LT*
Aux. switch (breaker) normally closed	*"b"*	Field weakening	*FW*	Low voltage	*LV*
Balanced voltage	*BV*	Final limit – forward	*FLF*	Main or line	*M*
Brake	*BR*	Final limit – reverse	*FLR*	Master switch	*MS*
Compensator-running	*MR*	Final limit – hoist	*FLH*	Maximum torque	*MT*
Compensator-starting	*MS*	Final limit – lower	*FLL*	Middle landing	*MLD*
Control	*CR*	Final limit – up	*FLU*	Motor field	*MF*
Door switch	*DS*	Final limit – down	*FLD*	Overload	*OL*
Down	*D*	Forward	*F*	Pilot motor	*PM*
Dynamic braking	*DB*	Full field	*FF*	Plug	*P*
Field accelation	*FA*	Generator field	*GF*	Reverse	*R*
Field deceleration	*FD*	High speed	*HS*	Series relay	*SR*
Field discharge	*FD*	Hoist	*H*	Slow down	*SD*
Field dynamic braking	*DF*	Jam	*J*	Thermostat	*TS*
Field failure (loss of field)	*FL*	Kick off	*KO*	Time	*T*
Field forcing (decreasing on variable voltage)	*DF*	Landing	*LD*	Up	*U*
		Limit switch	*LS*	Undervoltage	*UV*
				Voltage relay	*VR*

COILS

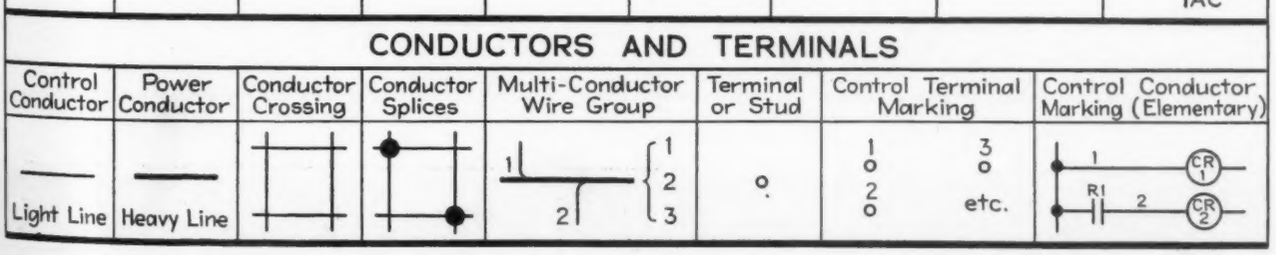




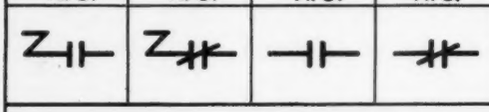
RESISTORS AND CAPACITORS

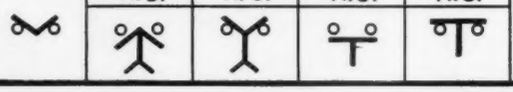


CONDUCTORS AND TERMINALS

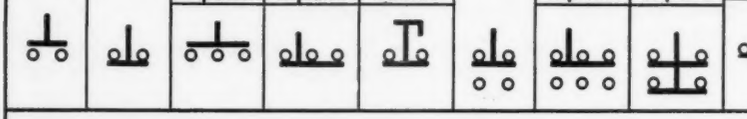


CONTACTORS

Main Circuit Contacts — Instantaneous Operation				Control Circuit Contacts		Timing Relay Contacts — Action Retarded When Coil Is				
With Blowout		Without Blowout				Energized			De-energized	
N.O.	N.C.	N.O.	N.C.	N.O.	N.C.	N.O.	N.C.	N.O.	N.O.	N.C.
										

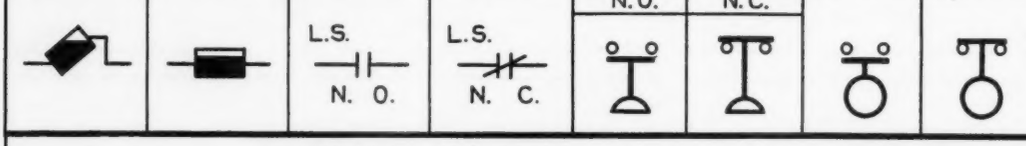
Overload Relay Contacts					Mechanical Connections		
Thermal	Magnetic				Connection or Shield	Fulcrum	Interlock
	Dash Pot (Delayed Trip)		Instant Trip				
	N.O.	N.C.	N.O.	N.C.			
							

CONTROL DEVICES

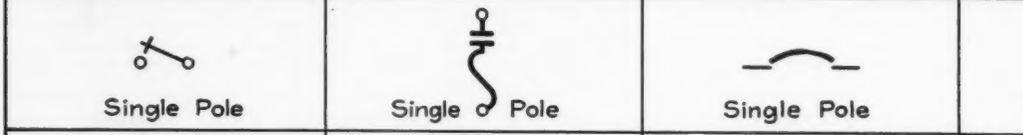
Push Buttons								Selector Switch		
N.O.	N.C.	N.O. 3 point	N.C. 3 point	N.C. Latch	Double Circuit	3 point	2 pole	Maintained Contact	N.O. A	N.C. B
										

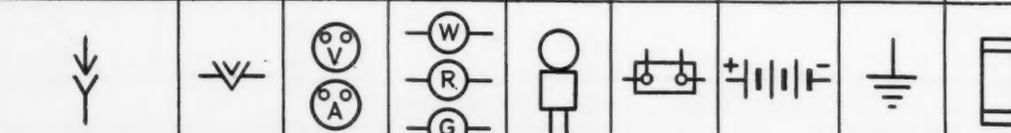
Typical Target

Pos.	Pole A	Pole B	
Auto.	X	O	↖
Hand	O	X	↗

Mercury Switch		Limit Switches		Pressure or Vacuum Switch		Float Switch		Plugging (Zero Speed or Friction) Switch
N.O.	N.C.	N.O.	N.C.	N.O.	N.C.	N.O.	N.C.	
								

KNIFE SWITCHES AND CIRCUIT BREAKERS

Manual Switch	Thermal Trip Breaker	Air Circuit Breaker	Oil Circuit Breaker
			
Single Pole	Single Pole	Single Pole	Single Throw
Multi Pole	Multi Pole	Multi Pole	Double Throw

MISCELLANEOUS

Disconnect Device (Plug or Coupling)	Test Jack	Meter	Indicating Lamp	Bell	Meter Shunt	Battery	Ground	Fuse	Brush and Slip Ring	Timer Motor